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Fingerprint Compression Technologies: A Review

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Abstract: Among many biometric recognition technologies, finger print recognition is very popular for personal identification due to the uniqueness, universality and invariance. Large volume of fingerprint is collected and stored everyday in a wide range of applications. In this context, the compression of these data may become imperative under certain circumstances due to the large amounts of data involved. This paper compares different compression standards like JPEG, JPEG-2000, WSQ, K-SVDetc. A new compression standards based on sparse representation also introduced. The experiments demonstrate that this is efficient compared with several competing compression techniques especially at high compression ratios.

Keywords: Compression; JPEG;JPEG 2000; K-SVD;WSQ.

I. INTRODUCTION

Generally, compression technologies can be classed into lossless and lossy. Lossless compression allows the exact original images to be reconstructed from the compressed data. Lossless compression technologies are used in cases where it is important that the original and the decompressed data are identical. When used in image compression where slight distortion is acceptable, lossless compression technologies are often employed in the output coefficients of lossy compression. Lossy compression technologies usually transform an image into another domain, quantize and encode its coefficients. During the last three decades, transform-based image compression technologies have been extensively researched and some standards have appeared. Two most common options of transformation are the Discrete Cosine Transform (DCT) [2] and the Discrete Wavelet Transform (DWT) [3].

Large volumes of fingerprints square measure collected and keep daily in an exceedingly big selection of applications, including forensics, access management etc., and square measure evident from the information of Federal Bureau of Investigation (FBI) . Associate automatic recognition of people supported fingerprints needs that the input fingerprint be matched with candidates within an outsized variety of fingerprints. Since giant volume of knowledge consumes additional amount of memory, the data contained in fingerprints should be compressed by extracting solely visible components. Fingerprint images exhibit characteristic high energy in bound high frequency bands ensuing from the ridge-valley pattern and alternative structures.

The DCT-based encoder is thought as compression of stream of 8X8 little blocks of images. This transform is used in JPEG [4]. The JPEG compression theme has several benefits like simplicity, catholicity and availability. However, it has a bad performance at low bit-rates due to the underlying block-based DCT scheme. For this reason, as early as 1995, the JPEG-committee began to develop a wavelet-based compression standard for still images, specifically JPEG- 2000[5]. The DWT-based algorithms include 3 steps: a DWT computation of the normalized image, division of the DWT coefficients and lossless coding of the quantity coefficients. Compared with JPEG, JPEG 2000 provides many options that support interactive access to large-sized image. It permits extraction of various resolutions, constituent fidelities, regions of interest etc.

Targeted at fingerprint images, there are special compression algorithms. The most common is Wavelet Scalar Quantization (WSQ)[6]. It became the FBI standard for the compression of 500 dpi fingerprint images. Inspired by the WSQ algorithm, a few wavelet packet based fingerprint compression schemes have been developed. But, these algorithms have a common problem, namely without the ability of learning the fingerprint images can't be compressed well now. So a novel approach based on sparse representation is given. Here features are extracted and represent them as dictionary atoms. In most Automatic Fingerprint identification System (AFIS)[1], the main feature used to match two finger print images are minutiae (ridges endings and bifurcations). Therefore, the difference of the minutiae between pre- and post-compression is considered in this paper.

II. Related Works

JPEG

For the past few years, a joint ISO/CCITT committee known as JPEG[4] (Joint Photographic Experts Group)has been working to establish the first international compression standard for continuous-tone still images, both grayscale and color. To meet the differing needs of many applications, the JPEG standard includes two basic compression methods, each with various modes of operation. A DCT-based method is specified for "lossy'' compression, and a predictive method for "lossless'' compression. JPEG has undertaken the ambitious task of developing a general-purpose compression standard to meet the needs of almost all continuous-tone still-image applications..

Algorithm

1. Divide the image into 8x8 sub blocks.

2. Apply DCT on the divided image (64 constants are going to obtained: one DC coefficient and sixty three AC coefficients).

3. Quantize the coefficients and therefore the lesser coefficients square measure set to zero.

5. Encode the coefficients using 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 because of the underlying block-based DCT scheme. For this reason, the JPEG-committee began to develop a new wavelet-based compression standard for still images, namely JPEG-2000.

JPEG-2000

In 1996, the JPEG committee began to think about the possibilities for a new still image compression standard to serve current and future applications. This initiative, which was named JPEG2000, has resulted in a comprehensive standard(ISO 15444 ITU-T Recommendation T.800) .The desire to provide a broad range of features for numerous applications in a single compressed bit-stream prompted the JPEG committee to investigate possibilities for a new compression standard. It have following advantage than JPEG.

- Improved compression efficiency.
- Lossy to lossless compression.
- Multiple resolution representation.
- Embedded bit-stream (progressive decoding and SNR scalability).
- Tiling.
- Region-of-interest (ROI) coding.

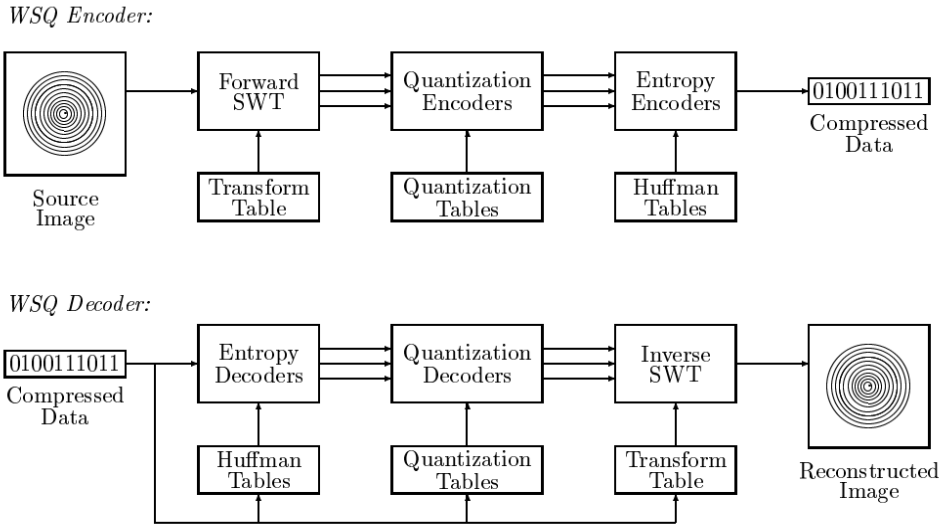
- Error resilience.

In JPEG 2000, DCT of JPEG is replaced with DWT(Discrete Wavelet Transform). The DWT-based algorithms include three steps: a DWT computation of the normalized image, quantization of the DWT coefficients and lossless coding of the quantized coefficients. Compared with JPEG, JPEG 2000 provides many features that support scalable and interactive access to large-sized image. It also allows extraction of different resolutions, pixel fidelities, regions of interest etc.

The above algorithms are for general image compression. Targeted at fingerprint images, there are special compression algorithms. The most common is Wavelet Scalar Quantization(WSQ). It became the FBI standard for the compression of 500 dpi fingerprint images.

WSQ

This is developed especially for fingerprint compressions. The WSQ compression technique developed by the FBI and alternative entities was designed to compress fingerprint pictures between ratios of ten to one and twenty to one. At these compression ratios, sufficient ridge and pore detail is maintained for the needs of identification, by fingerprint matching hardware or by human fingerprint examiners.



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

K-SVD

K-SVD[9](Single value decomposition) is an iterative method that alternates between sparse coding of the examples based on the current dictionary, and a process of updating the dictionary atoms to better fit the data. The update of the dictionary columns is combined with an update of the sparse representations, thereby accelerating convergence. The K-SVD algorithm is flexible and can work with any pursuit method (e.g., basis pursuit, FOCUSS, or matching pursuit[7]). We analyze this algorithm and demonstrate its results on both synthetic tests and in applications on real image data.The k-svd is not effective when the dictionary size is so large.So a new compression standard based on sparse approximation is introduced.

SAM

In SAM (Sparse Approximation Method), fingerprint is sliced into square patches which have the same size with the training patches. The size of the patches has a direct impact on the compression efficiency. The algorithm becomes more efficient as the size increases. In addition, to make the patches fit the dictionary better, the mean of each patch needs to be calculated and subtracted from the patch. After that, compute the sparse representation for each patch by solving the *l0* problem. Those co-efficient whose absolute values are less than a given threshold are treated as zero. For each patch, four kinds of information need to be recorded. They are the mean value, the number about how many atoms to use, the co-efficient and their locations. For improving algorithm, use orthogonal matching pursuit instead of matching pursuit for constructing the dictionary.

Algorithm

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1. For a given fingerprint divide it into patches.

2: For each patch its mean is calculated and subtracted from the patches.

3. For each patch, solve *l0* minimization by OMP method.

4: Those co-efficient whose absolute value less than a threshold are treated as zero.

5: Record the remaining coefficient

III. Experimental Study

Quality of compression depends on its C.R(Compression Ratio),PSNR(Peak Signal to Noise Ratio),and MSE(Mean Square Error) value.

Compression ratio, C.R is given by the formula,

$$C.R = n1/n2 \qquad (1)$$

where n1 is number of information carrying units in original image and n2, is number of information carrying units in compressed image.

In this section, we compare the proposed method with existing fingerprint compression algorithms. We use three different image compression algorithms, JPEG,JPEG 2000 and WSQ, which have been extensively described before. The standard JPEG is a part of almost any image processing tool we do not give further reference on it. The wavelet-based JPEG 2000 we use is provided by the Matlab.The WSQ algorithm is provided by a software downloaded on the Internet .

There are 2 groups of fingerprint images (referred to as DATABASE 1& DATABASE 2) are tested in the experiments.

DATABASE 1: 50 fingerprints are used to compare various compression technologies.

DATABASE 2: 80 fingerprints with size 300 × 300 are used to compare existing compression technology.

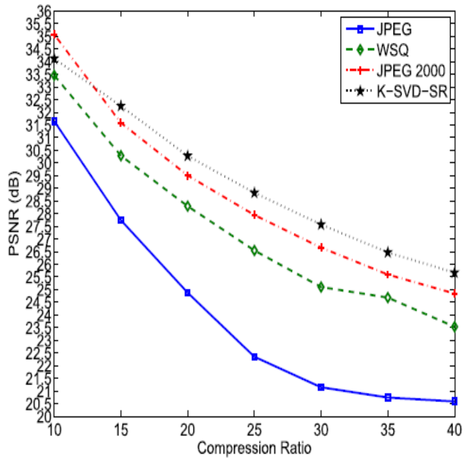

Fig:2 Average performance of algorithms JPEG, JPEG 2000 WSQ and Sparse at various compression ratios, on DATABASE 1

Fig.2 show the average performances of our proposed algorithms, JPEG, JPEG 2000 and WSQ. In the figure, 20 on the horizontal axis means a 20 : 1 compression ratio. Compared with JPEG and WSQ, the JPEG 2000's PSNR and sparse method's PSNR are consistently higher. The figure shows that the sparse algorithm outperforms the JPEG 2000 algorithm when the compression ratios are high. However, at compression ratio10: 1, JPEG 2000 works well than sparse compression. The reason is that the method based on sparse representation can't reflect the details well. This is the disadvantage of the kind of methods. When the compression ratios are high and the details are not important, these methods based on sparse representation have obvious advantage. This point also can be found in the comparative graph.

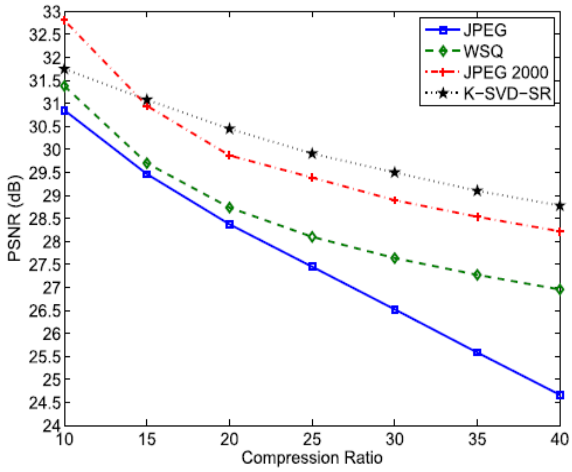

Fig:3 Average performance of algorithms JPEG, JPEG 2000 WSQ and Sparse at various compression ratios, on DATABASE 2.

Fig.3 show the average performances of the proposed algorithms, JPEG, JPEG 2000 and WSQ. The results on DATABASE 2 are roughly consistent with the results on DATABASE1. Compared with JPEG and WSQ, proposed sparse PSNR and JPEG 2000's PSNR are consistently higher. At compression ratio 10: 1, JPEG2000 works better than sparse, too. At compression ratio 15 : 1, the performance of sparse method is as good as that of JPEG 2000. At higher compression ratio, our algorithm outperforms the JPEG 2000.From the figure, we can see that the curve of our algorithm is the most flat. This means the rate of decay of our algorithm's PSNR is the slowest as the compression ratio increases.

IV. CONCLUSION

The different compression techniques adapted to compress the fingerprint image is reviewed and compared their Performance especially at high compression ratios. A new compression algorithm based on sparse approximation is also introduced. Two groups of fingerprint images are tested. The experiments show that sparse algorithm is efficient than competing compression techniques like JPEG, JPEG 2000, WSQ,K-SVD etc, especially at high compression ratio and can hold most of the minutiae robustly during the compression and reconstruction. However, the algorithm has higher complexities due to the block-by-block processing mechanism. Optimization of code of the different compression techniques has to be improved to reduce the complexity.

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