A Comparison of Lossless Compression Methods for Palmprint Images

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***Abstract*—In this work, lossless grayscale image compression methods are compared on a public palmprint image database. The total number of test images was about 7752, with 8 bit rates. The performance using different lossless compression algorithms on the compression ratios when processing palmprint sample data is investigated, in particular, we relate the application of CALIC, JPEG-LS,RAR, JPEG2000 (lossless version), PNG (Portable Network Graphics) LJPEG (lossless JPEG), JPEG (Binary DCT) and S+P transform. Based on the testing results using an open palmprint image database, CALIC gives high compression ratios in a reasonable time, whereas JPEG-LS is nearly as effective and very fast. A guide is given to choose lossless image compression algorithm.**

***Index Terms*—Biometrics; lossless image compression; palmprint image**

I. Introduction

Biometric traits are widely applied in local and remote authentication systems for advances of biometric recognition technologies. During the last decade, several algorithms and standards for compressing image data relevant in biometric systems have evolved. The transfer time of digital images depends on the size of the compressed images. The practical usefulness of a picture archiving and communication system (PACS) presupposes that transfer operations must fulfill reasonable time requirements. For example, Nigel M. Allinson et al present details of experiments to establish the optimum form of compression that provides realistic transmission times and yet does not affect the utility and integrity of the U.K. Fingerprint Service in searching for latent identifications and in archiving unidentified latents on the U.K. national automatic fingerprint identification system (AFIS) [1]. Nathanael proposed a novel lossless compression image method and showed that dictionary-based compression schemes can be as efficient as the current state-of-the-art compression schemes [2].

Biometric image loss compression has been investigated and some novel algorithms for special pattern in biometrical images has been propose, such as WSQ for fingerprint images [3]. Further, the loss compression effect on biometric recognition has been investigated, which is a guide for image storage [4-6]. However, the lossless image compression on the biometric image has little been concerned. Different biometric images have different main features, for example, the main feature of fingerprint images are their valley and ridge lines while the features of face image mainly exists in their low subspace. For low-resolution palmprint image, the features include line and rich texture information. Therefore, experimental results employed in different biometric image using different lossless compression algorithm is not the same. According to Ref. [7], JPEG2000 is suitable for iris images and PNG is suitable for fingerprints DB3. However, they do not discuss which lossless compression method is suitable to compress the palmprint image.

First of all analysis and test popular lossless image compression algorithms in the open palmprint, including those based on transformation (integer transform based in the JPEG and JPEG2000 system, as well as the SP-based transform coding method), based on predictive lossless compression algorithms (LJPEG, CALIC and JPEG-LS), dictionary-based compression methods (PNG and RAR).

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By testing on the PolyU palmprint database, analysis and comparison, we make a conclusion that the JPEG-LS system is suitable for lossless palmprint image compression for its compression efficiency and speed. The rest of this paper is organized as follows. In section II, different lossless image compression algorithms are reviewed. In section III, different lossless image compression algorithms are conducted on palmprint database are compared, including compression ratio and time-consuming performance. We also show that the JPEG-LS system is suitable for palmprint image compression. Conclusions are made in section IV.

II. OVERVIEW OF LOSSLESS COMPRESSION ALGORITHMS

A significant amount of work exists on using compression schemes in biometric systems. However, the attention is almost exclusively focused on lossy techniques since in this context the impact of compression to recognition accuracy needs to be investigated. For example, in [8], the impact of JPEG, JPEG2000, SPIHT, PRVQ, and fractal image compression on recognition accuracy of selected fingerprint and face recognition systems have been investigated.

One of the few results on applying lossless compression techniques exploits the strong directional features in fingerprint images caused by ridges and valleys. A scanning procedure following dominant ridge direction has shown to improve lossless coding results as compared to JPEG-LS and PNG[9]. A list of lossless image compression algorithms is reviewed as follows.

JPEG2000 JPEG 2000, as noted previously, is the next ISO/ITU-T standard for still image coding. In the following, we restrict the description to Part I of the standard, which defines the core system. Part II will provide various extensions for specific applications, but is still in preparation. JPEG 2000 is based on the discrete wavelet transform (DWT), scalar quantization, context modeling, arithmetic coding and post-compression rate allocation. The DWT is dyadic and can be performed with either the reversible Le Gall (5,3) taps filter9, which provides for lossless coding, or the non-reversible Daubechies (9,7) taps biorthogonal one, which provides for higher compression but does not do lossless. The quantizer follows an embedded dead-zone scalar approach and is independent for each sub-band. Each sub-band is divided into rectangular blocks (called code-blocks in JPEG 2000), typically 64x64, and entropy coded using context modeling and bit-plane arithmetic coding.

JPEG (lossless version) Different from the standard JPEG, the JPEG lossless version takes place of the binary DCT (integer DCT) instead of traditional DCT.

S+P transform For lossless image compression, similar to the wavelet transform, Said and William A. Pearlman proposed an integer multiresolution transformation, which was called S+P transform[10]. It uses a simple pyramid multiresolution scheme which is enhanced via predictive Coding. The new transformation is similar to the subband decomposition, but it uses only integer operations. The number of bits required to represent the transformed image is kept small though careful scaling and truncations. It can be computed with a small computational effort, using only integer additions and bit-shifts. It solves the finite-precision problem by carefully truncating the transform coefficients during the transformation (instead of after). A codec uses this transformation to yield efficient progression up to lossless recovery.

JPEG-LS is the latest ISO/ITU-T standard for lossless coding of still images. It reference encoder LOCO using Median edge detection and Subsequent predictive and Golumb encoding (in two modes: run and regular modes)[11]. JPEG-LS5is the latest ISO/ITU-T standard for lossless coding of still images. It also provides for “near-lossless” compression. Part-I, the baseline system, is based on adaptive prediction, context modeling and Golomb coding. In addition, it features a flat region detector to encode these in run-lengths. Near-lossless compression is achieved by allowing a fixed maximum sample error. Part-II will introduce extensions such as an arithmetic coder, but is still under preparation. This algorithm was designed for low-complexity while providing high lossless compression ratios. However, it does not provide support for scalability, error resilience or any such functionality.

CALIC, a Context based, Adaptive, lossless Image Codec [12] is a compression technique based on the pixel context of the present pixel to be coded (i.e. the setting of the pixels of some predetermined pattern of neighbour pixels). The method is capable of learning from the errors made in the previous predictions and in this way it can improve its prediction adaptively when the compression proceeds. This estimate is the average error of the previous prediction values in the present context. The context for error estimation is selected in such a way that it models the magnitudes of the local gradient and the two previous error values both in relation to the local texture of the image and the prediction value in the most effective way. Four coefficients are used to weight the horizontal and vertical gradient magnitudes and the previous prediction errors, when calculating the context for error estimation. The coefficients should be selected on the basis of the training set drawn from the type of images to be compressed. The final set of prediction errors is coded by arithmetic or Huffman coding.

Lossless JPEG(L-JPEG) was developed as a late addition to JPEG in 1993, using a completely different technique from the lossy JPEG standard[13]. It uses a predictive scheme based on the three nearest (causal) neighbors (upper, left, and upper-left), and entropy coding is used on the prediction error. It is not supported by the standard Independent JPEG Group libraries, although Ken Murchison of Oceana Matrix Ltd. wrote a patch that extends the IJG library to support Lossless JPEG. Lossless JPEG has some popularity in medical imaging, and is used in DNG and some digital cameras to compress raw images, but otherwise was never widely adopted.

LibJPEG with default Huffman tables and PSV=1.The *JPEG (Joint Photographics Experts Group)* standard for lossless compression LJPEG is based on a prediction method combined with the entropy coding. The prediction method transforms the original image to an error image with reduced variance using a predictor, which is initially chosen among eight possible predictors. The prediction is a function of some of the three previous neighboring pixels (pixels to the left, above and upper-left of the current pixels). The error image is finally compressed using Huffman or arithmetic coding. At the time of this writing, the Independent JPEG Group's lossless JPEG image compression package, a free implementation of the lossless JPEG standard, is available by anonymous ftp from ftp://ftp.cs.cornell.edu/pub/multimed/ljpg.

PNG is essentially a file format for lossless compression and storage of images[14]. Portable Network Graphics (PNG) is a W3C recommendation for coding of still images which has been elaborated as a patent free replacement for GIF, while incorporating more features than this last one. It is based on a predictive scheme and entropy coding. The prediction is done on the three nearest causal neighbors and there are five predictors that can be selected on a line-by-line basis. The entropy coding uses the Deflate algorithm of the popular Zip file compression utility, which is based on LZ77 coupled with Huffman coding. PNG is capable of lossless compression only and supports gray scale, paletted color and true color, an optional alpha plane, interlacing and other features.

WinRAR is a shareware file archiver and data compression utility developed by Eugene Roshal, and first released in autumn of 1993. It is one of the few applications that is able to create RAR archives natively, because the encoding method is held to be proprietary. The current developer is Eugene Roshal, while his brother Alexander Roshal is engaged in running the business behind the software. Complete support for RAR (WinRAR native conversion format) and ZIP archives, and unpacking of ARJ, LZH, TAR, GZ, ACE, UUE, BZ2, JAR, ISO, EXE, 7z, and Z archives. These algorithms are based on dictionary for general text compression. The followings are some example. 7z uses LZMA as compression procedure which includes an improved LZ77 and ranger encoder, BZ2 concatenates RLE, Burrows-Wheeler transform and Huffman coding, GZ uses a combination of LZ77 and Huffman encoding. RAR uses LZSS and solid archiving for the compression of multiple files. UHA supports several algorithms out of which ALZ has been used. ALZ is optimized LZ77 with an arithmetic entropy encoder. ZIP uses the DEFLATE algorithm, similar to GZ.

III. EXPERIMENTS AND DISCUSSIONS

The experimental performance was conducted on the Hong Kong Polytechnic University (PolyU) Palmprint Database, which can be downloaded from website (http://www4.comp.polyu.edu.hk/~biometrics/). The PolyU Palmprint Database contains 7752 grayscale images in BMP image format, corresponding to 386 different palms. In this database, around 20 samples from each of these palms were collected in two sessions, where around 10 samples were captured in the first session and the second session, respectively. The resolution of all the original palmprint images is 384 × 284 pixels at 75 dpi. In our paper, palmprint is orientated and the ROI, whose size is 128×128, is cropped. Figure.1 shows the palmprint samples and their ROI parts.

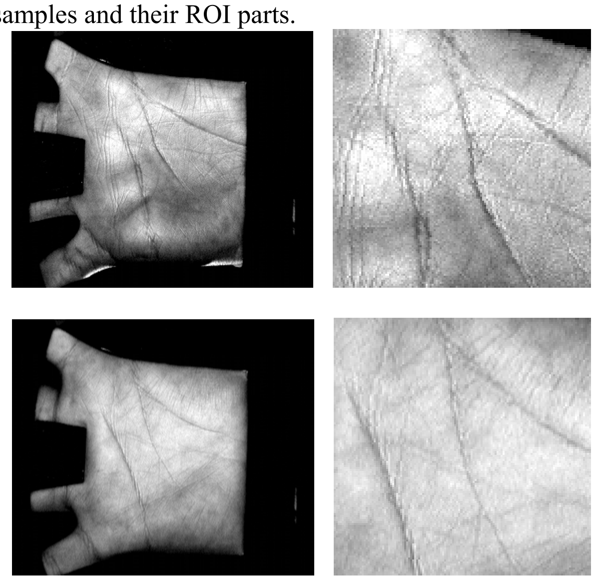

Figure.1 the palmprint samples and their ROI parts

The results have been generated on a PC r with an Intel Pentium 4 processor (2.66 GHz) and 4GB RAM configured with Microsoft Windows 7 and visual C++ 6.0. To obtain the speed performance under the same conditions all the lossless image compression programs are re-compiled on win7 with visual C++. The software implementations used for coding the images are:

JPEG2000 is the current JPEG lossy compression standard but is operated in its lossless mode, the JPEG 2000 software (http://www.kakadusoftware.com) version 2.3.2, he Lossless JPEG codec of Cornell University(ftp://ftp.cs.cornell.edu/pub/multimed), version 1.0. the JPEG (Lossless Mode, binary DCT, http://www.ensc.sfu.ca/~jiel/software/), lossless image compression based on SP transform (http ：//ipl.rpi.edu/spiht).

CALIC is a Context-based Adaptive Lossless Image Coding scheme, an arithmetic encoder is internally used, CALIC (ftp://ftp.csd.uwo.ca/pub/from_wu/).

JPEG-LS is the current JPEG lossless compression standard, the SPMG JPEG-LS implementation of the University of British Columbia (http://spmg.ece.ubc.ca/), version 2.2. The PNG compression testing software is developed based on libpng version 1.4.5 and zlib 1.2.3 (It is a general purpose data compression library), http://www.libpng.org/pub/png/libpng.html.

We measure the compression result by the compression ratio R=(original image size)/(compressed image size) ,Thus, larger values of *R* indicate a better compression method. It should be noted that the original image size used in the above formula contains the BMP header information or the byte border alignments.

Usually, the bpp (bits per pixel) is used to measure the compression efficiency, which has the relation with compression ratio R, bpp=8/R.

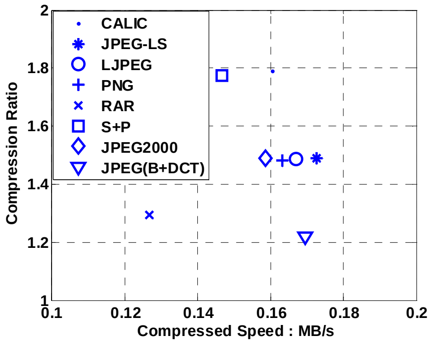

Figure.2 Compression ratios and compression speed (MB/s)for lossless compression methods. Total file sizes have been used in the speed calculations.

Figure.2 illustrates the (time/compression ratio) tradeoff of the compression methods. The results are averages of all test runs performed. JPEG-LS and CALIC compare favorably with the other methods. The compression ratio of S+P is relatively good but the method suffers from the long running time. Table 1 shows the compression results for 8 general compression programs. These were tested for all the palmprint images in the database, and it gives the average performance. The CALIC results for these studies are included for comparison. The averages are unweighted and therefore be used with caution. From Table 1, we can see that the average compression ratio is about 1.2~1.8 for palmprint images. The CALIC is the highest algorithm respect to compression ratio while the JPEG-LS the fastest compression method. For JPEG using binary DCT version, it just use binary instead of traditional DCT, therefore, the compression efficiency is very low. Usually, the Winrar software is very suitable for compressing text files and is not suitable for compression multimedia files, such as video, image or audio files. The experimental results also confirm this property.

TABLE I.
EXPERIMENTAL PERFORMANCE UNDER DIFFERENT LOSSLESS COMPRESSION ALGORITHMS

compression algorithm	CALIC	JPEG-LS	LJPEG （PSV=7）	PNG
Time(s)	805	748	773	791
Compression ratio	1.7908	1.4886	1.4879	1.4806
Bpp	4.4673	5.3743	5.3766	5.4031

compression algorithm	RAR -3.93	S+P	JPEG2000	JPEG (B+DCT)
Time(s)	1019	880	814	761
Compression ratio	1.2942	1.7742	1.4894	1.2209
Bpp	6.1813	4.5092	5.3712	6.5524

JPEG-LS, LJPEG and PNG show nearly the same compression ratio. However, JPEG-LS has advantage in the compression speed. Overall, LOCO-I seems to be the best compromise between compression results and time consuming. Therefore, the employment of JPEG-LS in biometric palmprint systems can be recommended for most scenarios which confirm the standardization done in ISO/IEC 19794.

IV. CONCLUSIONS

To provide a comparison of the efficiency for palmprint images that can be expected from a number of recent as well as most popular still lossless image coding algorithms, we test different lossless image algorithms on palmprint images in the open database. According to the testing results, JPEG-LS is the fastest while the CALIC is the most compression ratio. The compression ratios with the four best methods(CALIC, S+P, JPEG-LS) does not reach 2. Therefore, a topic for discussion is whether a limited and selective application of lossy compression techniques could be allowed in palmprint imaging.

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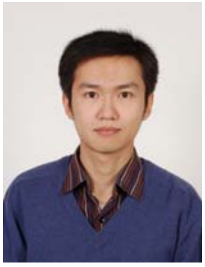

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