Experiments on Improving Lossless Compression of Biometric Iris Sample Data

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***Abstract*—The impact of using different lossless compression algorithms when compressing biometric iris sample data from several public iris databases is investigated. In particular, we relate the application of dedicated lossless image codecs like JPEG-LS, CALIC, and PNG, lossless variants of lossy codecs like JPEG2000 and JPEG XR, and two general purpose compression schemes to rectilinear iris sample imagery from seven public databases. The application of additional prediction as a preprocessing strategy as well as a conversion to a set of binary images to enable JBIG application is evaluated. The results are discussed in the light of the recent ISO/IEC FDIS 19794-6 and ANSI/NIST-ITL 1-2011 standards and IREX recommendations.**

***Index Terms*—iris recognition, lossless image compression, biometrics**

I. Introduction

With the increasing usage of biometric systems the question arises naturally how to store and handle the acquired sensor data (denoted as sample data subsequently). In this context, the compression of these data may become imperative under certain circumstances due to the large amounts of data involved. Among other possibilities (e.g. like compressed template storage on IC cards and optional storage of (encrypted) reference data in template databases), compression technology is applied to sample data in distributed biometric systems, where the data acquisition stage is often dislocated from the feature extraction and matching stage (this is true for the enrollment phase as well as for authentication). In such environments the sample data have to be transferred via a network link to the respective location, often over wireless channels with low bandwidth and high latency. Therefore, a minimization of the amount of data to be transferred is highly desirable, which is achieved by compressing the data before transmission.

In order to maximize the benefit in terms of data reduction, lossy compression techniques are often suggested. However, the distortions introduced by compression artifacts may interfere with subsequent feature extraction and may degrade the matching results. As an alternative, lossless compression techniques can be applied which avoid any impact on recognition performance but are generally known to deliver much lower compression rates. An additional advantage of lossless compression algorithms is that these are often less demanding in terms of required computations as compared to lossy compression technology which is beneficial for the sketched target-scenario often involving weak or low-power sensing devices.

During the last decade, several algorithms and standards for compressing image data relevant in biometric systems have evolved. The certainly most relevant one is the ISO/IEC 19794 standard on "Biometric Data Interchange Formats", where in its former version (ISO/IEC 19794-6:2005), JPEG and JPEG2000 (and WSQ for fingerprints) were defined as admissible formats for lossy compression, whereas for lossless and nearly lossless compression JPEG-LS as defined in ISO/IEC 14495 was suggested. In the most recently published draft version (ISO/IEC FDIS 19794-6 as of August 2010), only JPEG2000 is included for lossy compression while the PNG format serves as lossless compressor. These formats have also been recommended for various application scenarios and standardized iris images (IREX records) by the NIST Iris Exchange (IREX `http://iris.nist.gov/irex/`) program.

The ANSI/NIST-ITL 1-2011 standard on "Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information" (2nd draft as of February 2011, former ANSI/NIST-ITL 1-2007) supports both PNG and JPEG2000 for the lossless case and JPEG2000 only for applications tolerating lossy compression.

In literature, a significant amount of work exists on using compression schemes in biometric systems. However, the attention is almost exclusively focussed on lossy techniques since in this context the impact of compression to recognition accuracy needs to be investigated (see e.g. for iris imagery [1], [2]).

A (smaller) set of lossless compression schemes has been compared when applied to image data from several biometric modalities like fingerprints, hand data, face imagery, retina, and iris [3] (only a single dataset, MMU1 from this current work, has been used). In recent work [4], we have focused on polar iris image data when subjected to an extended set of lossless compression schemes.

In this work, we focus on lossless compression of rectilinear iris sample imagery (corresponding to IREX KIND1 or KIND3 records) as contained in several public iris databases. In particular, we investigate possible means how to apply non-standard techniques as preprocessing to common lossless compression schemes in order to improve compression ratios.

One of the aims is to validate whether the lossless algorithm to be included in ISO/IEC FDIS 19794-6 (which is PNG) actually represents the best solution in terms of compression and how the scheme could eventually be improved.

In Section 2 we briefly describe the applied algorithms / software and the biometric data sets used. Section 3 presents and discusses results with respect to achieved compression ratios Section 4 concludes this work.

II. Experimental Settings and Methods

A. Compression Algorithms

We employ 3 dedicated lossless image compression algorithms (JPEG-LS to CALIC), 2 lossy image compression algorithms with their respective lossless settings (JPEG2000 and JPEG XR), 2 lossless binary image compression algorithms (JBIG-1 and JBIG-2) as well as 2 general purpose lossless data compression algorithms (which turned out to be best suited for this application context [3], [4]):

JPEG-LS IrfanView[1] is used to apply JPEG-LS which is based on using Median edge detection and subsequent predictive and Golumb encoding (in two modes: run and regular mode).

PNG is used from the Imagemagick implementation[2] using an LZSS encoding variant, setting compression strength to the maximum of 9 (and no filter set).

CALIC uses edge-based prediction similar to but more sophisticated than JPEG-LS followed by context-based adaptive arithmetic encoding[3].

JPEG2000 The Jasper standard reference implementation library[4] is used to apply JPEG2000 Part 1, a wavelet-based lossy-to-lossless transform coder.

JPEG XR The "Information technology JPEG XR image coding system Reference software ISO/IEC 29199-5" is used to apply this most recent ISO still image coding standard, which is based on the Microsoft HD format.

JBIG-1 applies (optional hierarchical) context adaptive binary arithmetic encoding for the lossless compression of binary images[5].

JBIG-2 generalizes JBIG-1 to compound image data formats employing a similar compression image to unspecified (i.e. non-text, non-halftone) image areas[6].

7z uses LZMA as compression procedure which includes an improved LZ77 and range encoder. We use the 7ZIP software[7] applying options `a -mx9`.

UHA supports several algorithms out of which ALZ-2 has been used (option `uharc a -m3`). ALZ-2 is optimized LZ77 with an arithmetic entropy encoder. The UHARC software is employed[8].

[1] http://www.irfanview.com/
[2] http://www.imagemagick.org/
[3] http://compression.graphicon.ru/download/sources/i_glless/codec.zip
[4] http://www.ece.uvic.ca/ mdadams/jasper/
[5] http://www.cl.cam.ac.uk/ mgk25/jbigkit/
[6] https://github.com/agl/jbig2enc
[7] http://downloads.sourceforge.net/sevenzip/7za920.zip
[8] ftp://ftp.sac.sk/pub/sac/pack/uharc06b.zip

Apart from applying these schemes in standard mode, we investigate two options which can be seen as a sort of pre-processing. First, we apply a Median edge detection prediction as used in JPEG-LS before applying the above-listed schemes to the prediction residual. This is meant to test if we can improve compression with this in-advance prediction stage. Second, we conduct a conversion from 8bpp grayscale images to 8 binary images to be able to apply JBIG-1 and JBIG-2 (this strategy is also used as a preprocessing for 7z and UHA). This is done in two modes: classical binary representation as well as binary Gray code where in the latter mode, intercorrelations among adjacent bitplanes are better reflected.

B. Sample Data

For all our experiments we used the images in 8-bit grayscale information per pixel in .bmp or .pgm format since all software can handle these format (.bmp and .pgm share identical file size). Database imagery has been converted into this format if not already given so, color images have been converted to the YUV format using the Y channel as grayscale image. Only images that could be compressed with all codecs have been included into the testset as specified below. We use the images in their respective original resolutions (as rectilinear iris images).

CASIA V2 (device 1) database[9] consists of 2600 images with 640×480 pixels in 8 bit grayscale .bmp format.

CASIA V3 Interval database (same URL as above) consists of 2639 images with 320×280 pixels in 8 bit grayscale .jpeg format.

MMU1 database[10] consists of 457 images with 320×240 pixels in 24 bit grayscale .bmp format.

MMU2 database (same URL as above) consists of 996 images with 320×238 pixels in 24 bit color .bmp format.

UBIRIS database[11] consists of 1876 images with 200×150 pixels in 24 bit color .jpeg format.

BATH database[12] consists of 1000 images with 1280×960 pixels in 8 bit grayscale .jp2 (JPEG2000) format.

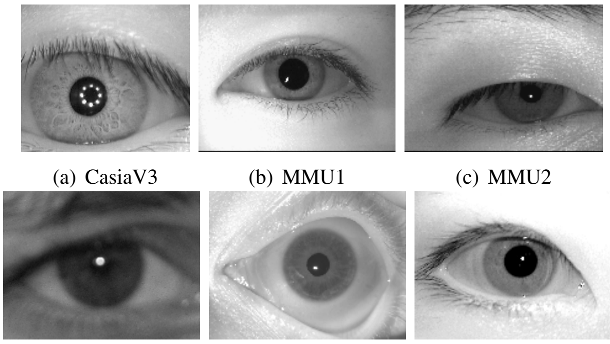
ND Iris database[13] consists of 1801 images with 640×480 pixels in 8 bit grayscale .tiff format.

Figure 1 provides example images from databases as used in the experiments. As can be seen, the image resolutions (and file sizes) as well as the amount of redundancies (e.g. share of background area) vary tremendously among the different datasets, therefore, we may expect significantly varying compression ratios.

III. Experimental Results

In the subsequent plots, we display the achieved averaged compression ratio per database for the different algorithms. The blue bars indicate the direct application of the compression algorithms (called "direct mode" subsequently) while the

[9] http://http://www.cbsr.ia.ac.cn/IrisDatabase.htm/
[10] http://pesona.mmu.edu.my/ ccteo/
[11] http://www.di.ubi.pt/ hugomcp/investigacao.htm
[12] http://www.irisbase.com/
[13] http://www.nd.edu/ cvrl/CVRL/Data_Sets.html



(a) CasiaV3 (b) MMU1 (c) MMU2
(d) UBIRIS (e) BATH (f) ND Iris

Fig. 1. Example iris images from the databases.

red bars show the effect of applying the JPEG-LS predictor as preprocessing ("predictive mode").

The results for the CASIA V3 Interval database may serve as a prototypical example as shown in Fig. 2. In direct mode, CALIC is the best technique closely followed by JPEG-LS and JPEG2000. PNG is by far the least efficient compression scheme. The general purpose compressors cannot compete with the image-tailored algorithms apart from PNG. JPEG XR delivers disappointing performance.

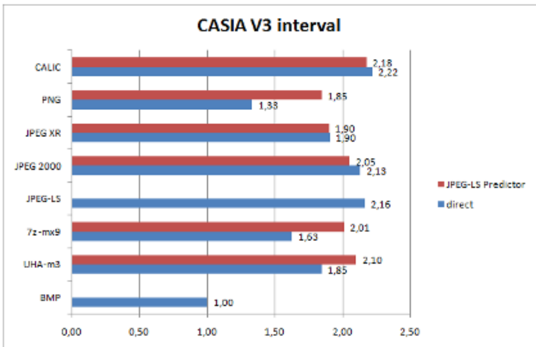


Fig. 2. CASIA V3 Interval results.

The results of the predictive mode are interesting. The top performing techniques (CALIC and JPEG2000) are not improved but compression ratio is even slightly reduced on the one hand. On the other hand, for PNG, UHA, and 7z we observe a significant increase in compression ratio. Obviously, in direct mode, these techniques are not able to capture spatial redundancies sufficiently which are then reduced by the Median edge predictor.

For the BATH and the MMU2 database the results are very similar (not displayed) apart from the fact that JPEG2000 is the best technique for the BATH dataset (which is explained by the native format being JPEG2000 for these images) and JPEG-LS is the best algorithms for MMU2. Additionally, the improvements of UHA and 7z in predictive mode are less significant for MMU2.

Fig. 3 show the results for the MMU1 database which are rather different. The top performing technique in direct more is UHA, followed by CALIC and JPEG-LS. The only technique which is able to take advantage of the predictive mode is PNG for this dataset, but the improvement is also moderate. All other techniques exhibit a moderate decrease in compression ratio when predictive mode is being applied.

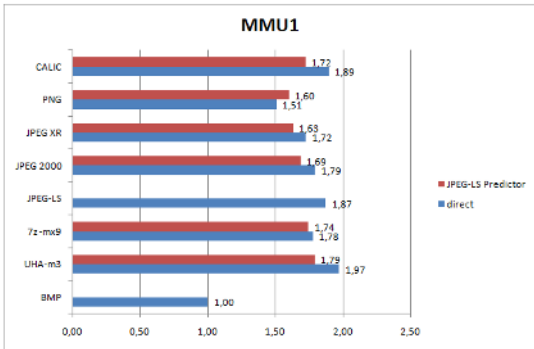


Fig. 3. MMU1 results.

The compression ratio of JPEG2000 clearly below 2.0 significantly contradicts to the results provided in earlier work [3], where JPEG2000 excels in compressing iris images of the MMU1 database (XN-View has been used). In order to investigate this in more detail, we conduct JPEG2000 compression on this dataset with four different additional software packages.

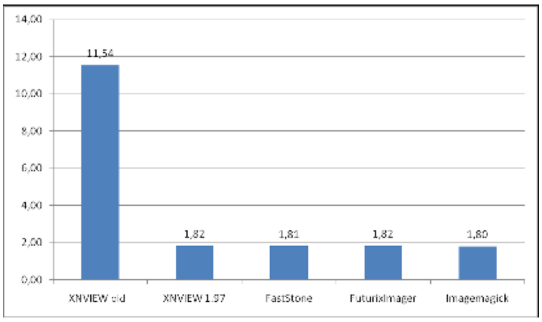


Fig. 4. Compression ratios with 4 JPEG2000 implementations (MMU1).

Fig. 4 shows that indeed with an older version of XN-View (the version as being used in [3]) very high compression ratios could be achieved, while a newer version and two other implementations provide results consistent to those obtained in this work with Jasper. When looking into this with more detail, it turns out that JPEG2000 compression in the older XN-View version was indeed lossy (but incorrectly stated as being lossless), which explains the high compression ratio.

The results for the ND iris database are in perfect accordance to the MMU1 results. For the UBIRIS dataset, the top performing schemes are again CALIC, JPEG-LS, and JPEG2000 in direct mode, PNG is clearly the worst technique. Only PNG is able to take significant advantage of the predictive mode, 7z compression is slightly improved, while UHA results are even slightly worsened.

In the following, we discuss the results in case of having converted the pictorial data into a set of 8 binary images.

Green and purple bars depict the results when using Gray-code representation (the former in direct mode and the latter in predictive mode), while blue and red bars show the results of the classical binary format (again the former in direct mode and the latter in predictive mode). Fig. 5 shows the results for the CASIA V3 Interval dataset, which exhibit typical trends also valid for other datasets. Both results in Gray-code representation (in direct and predictive mode) are always better as compared to the better result in classical binary representation. Therefore, we only discuss Gray-code based results in the following. The direct mode is inferior to the predictive mode as shown in the figure, however, this is only the case for the CASIA V2 (dev. 1), CASIA V3 Interval, and BATH datasets. For the other datasets differences are not significant and in some cases the direct more is slightly better.

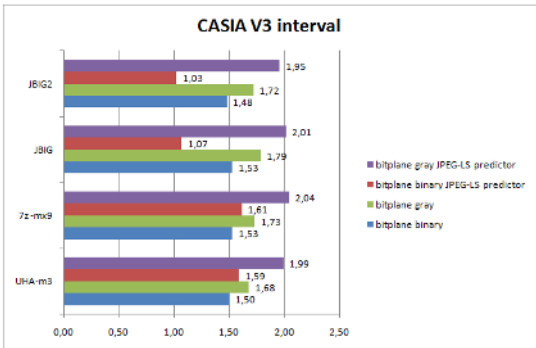


Fig. 5. CASIA V3 Interval results: bitplane compression.

JBIG-1 and JBIG-2 based compression never reaches the compression ratios of the three best performing algorithms for any database, however, in direct mode results are always better as compared to PNG results and for predictive mode this is also true except for the UBIRIS dataset. For the general purpose compression schemes, converting the data into binary representation always worsens the results except for 7z and the CASIA V3 Interval dataset as shown in the figure.

In Table I, we show the best and worst technique for each database (where schemes involving conversion to classical binary representation are not considered). While we notice some differences concerning the best algorithm, PNG is consistently the worst technique. The achieved compression ratio are of course highly correlated to the resolution of the image material.

	Best	Ratio	Worst	Ratio
CASIA V2 (dev. 1)	JPEG-LS	3.17	PNG	1.81
CASIA V3 Int.	CALIC	2.22	PNG	1.33
MMU1	CALIC	1.89	PNG	1.51
MMU2	JPEG-LS	2.29	PNG	1.55
UBIRIS	CALIC	1.56	PNG	1.13
BATH	JPEG2000	4.24	PNG	2.10
ND Iris	UHA	2.07	PNG	1.55

TABLE I

BEST AND WORST COMPRESSION ALGORITHM FOR EACH DATABASE WITH CORRESPONDING ACHIEVED COMPRESSION RATIO.

IV. CONCLUSION

Overall, CALIC and JPEG-LS have found to be the best performing algorithms for most datasets and their results are very close in any case. Therefore, the employment of JPEG-LS in iris recognition systems can be recommended for most scenarios which confirms the earlier standardization done in ISO/IEC 19794-6. The current choice for a lossless compression scheme in the recent ISO/IEC FDIS 19794-6 and ANSI/NIST-ITL 1-2011 standards relying on PNG on the other hand does not seem to be very sensible based on the results of this study since PNG was found to be the worst performing algorithm included in this current investigation. Moreover, as shown recently in [3], JPEG-LS turns out to be also significantly faster compared to PNG.

Performing an additional prediction stage as a preprocessing technique was found to be effective only for PNG for all datasets and for the two general purpose compression algorithms 7z and UHA for some datasets. For the top performing algorithms, additional prediction slightly decreased compression performance. The ease of improving PNG compression results by applying additional prediction again underlines the suboptimality of this technique as compared to state of the art still image compression schemes.

Representing grayscale images as a set of binary images enables the application of compression standards for binary images like JBIG-1,2. While not being competitive to the top performing grayscale compression algorithms, such techniques easily outperform PNG and when combined with predictive coding, even are competitive to JPEG XR.

ACKNOWLEDGEMENTS

Most of the work described in this paper has been done in the scope of the ILV "Compression Technologies and Data Formats" (winter term 2010/2011) in the master program on "Communication Engineering for IT" at Carinthia Tech Institute. The artificial name "Georg Weinhandel" represents the following group of students working on this project: Marco Blatnik, Ernesto Chavez, Harald Goriupp, Kurt Horvath, Dagem Alemayehu Goshu, Daniel Hofer, Bohdan Kaspryshyn, Markus Lagler and Emanuel Pachoinig. This work has been partially supported by the Austrian Science Fund, TRP project no. L554-N15.

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