# Lossless Compression of Polar Iris Image 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, the application of dedicated lossless image codecs (lossless JPEG, JPEG-LS, PNG, and GIF), lossless variants of lossy codecs (JPEG2000, JPEG XR, and SPIHT), and a few general purpose file compression schemes is compared. We specifically focus on polar iris images (as a result after iris detection, iris extraction, and mapping to polar coordinates). The results are discussed in the light of the recent ISO/IEC FDIS 19794-6 standard and IREX recommendations.

## 1 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. For example, in distributed biometric systems, the data acquisition stage is often dislocated from the feature extraction and matching stage (this is true for the enrolment 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 minimisation of the amount of data to be transferred is highly desirable, which is achieved by compressing the data before transmission.

Having found that compression of the raw sensor data can be advantageous or even required in certain applications, we have to identify techniques suited to accomplish this task in an optimal manner. In order to maximise the benefit in terms of data reduction, lossy compression techniques have to be applied. 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.

In this work, we experimentally assess the the application of several lossless compression schemes to iris image sample data as contained in several public iris databases. In Section 2, we briefly review related work on biometric sample data compression. Section 3 is the experimental study where we first describe the applied algorithms / software and biometric data sets. Subsequently, results with respect to achieved compression ratios for polar iris image sets and selected recangular image data sets are discussed. Section 4 concludes this work.

## 2 Biometric Sample Compression

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 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.

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. 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 [1]. In recent work [2] a 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.

In the subsequent experimental study we will apply an extended set of lossless compression algorithms to image data from different public iris image databases. Extensive results with respect to achieved compression ratio are shown. Specifically, we focus on polar iris images (as a result after iris detection, iris extraction, and mapping to polar coordinates, corresponding to KIND16 IREX records). While in the former version of the corresponding standard this type of imagery has been covered (ISO/IEC 19794-6:2005), the most recently published version (ISO/IEC FDIS 19794-6 as of August 2010) does no longer include this data type (based on the IREX recommendations). However, for applications not focussing on data exchange with other systems this data type can still be an option due to the extremely low data volume. In addition, employing this data type in a distributed biometric system shifts iris detection, extraction, and rectangular warping away from the feature extraction / matching device to the acquisition device since these operations are performed **before** compression and transmission. This can be of advantage in situations where the feature extraction / matching device is highly busy due to identification-mode operations (e.g.

consider a scenario where numerous surveillance cameras submit data to the feature extraction and matching device for identification) and therefore can lead to higher throughput of the entire system. Also in applications where reference data is stored in encrypted manner in databases and decrypted for each matching procedure a small data amount is favourable to minimize the effort required for repeated decryption operations.

## 3 Experimental Study

### 3.1 Setting and Methods

**Compression Algorithms** We employ 4 dedicated lossless image compression algorithms (lossless JPEG – PNG), 3 lossy image compression algorithms with their respective lossless settings (JPEG2000 – JPEG XR), and 5 general purpose lossless data compression algorithms:

**Lossless JPEG** Image Converter Plus[3] is used to apply lossless JPEG, the best performing predictor (compression strength 7) of the DPCM scheme is employed.

**JPEG-LS** IrfanView[4] 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 modes) [3].

**GIF** is used from the XN-View software[5] employing LZW encoding.

**PNG** is also used from the XN-View implementation using an LZSS encoding variant setting compression strength to 6.

**JPEG2000** Imagemagick[6] is used to apply JPEG2000 Part 1, a wavelet-based lossy-to-lossless transform coder.

**SPIHT** lossy-to-lossless zerotree-based wavelet transform codec[7].

**JPEG XR** FuturixImager[8] is used to apply this most recent ISO still image coding standard, which is based on the Microsoft HD format.

**7z** uses LZMA as compression procedure which includes an improved LZ77 and range encoder. We use the 7ZIP software[9].

**BZip2** concatenates RLE, Burrows-Wheeler transform and Huffman coding, also the 7ZIP software is used.

**Gzip** uses a combination of LZ77 and Huffman encoding, also the 7ZIP software is used.

**ZIP** uses the DEFLATE algorithm, similar to Gzip, also the 7ZIP software is used.

**UHA** supports several algorithms out of which ALZ-2 has been used. ALZ is optimised LZ77 with an arithmetic entropy encoder. The WinUHA software is employed[10].

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3 http://www.imageconverterplus.com/

4 http://irfanview.tuwien.ac.at

5 http://www.xnview.com/

6 http://www.imagemagick.org/script/download.php

7 http://www.cipr.rpi.edu/research/SPIHT

8 http://fximage.com/downloads/

9 http://www.7-zip.org/download.html

10 http://www.klaimsoft.com/winuha/download.php

**Sample Data** For all our experiments we used the images in 8-bit grayscale information per pixel in .bmp format since all software can handle this format (except for SPIHT which requires a RAW format with removed .pgm headers). Database imagery has been converted into this format if not already given so, colour 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 rectangular iris images) and in form of polar iris images, which correspond to iris texture patches in polar coordinates which are obtained after iris segmentation and log-polar mapping. For generating these latter type of images, we use an open-source MatLAB iris-recognition implementation which applies a 1D Gabor-filter version of the Daugman iris code strategy [4] for iris recognition[11]. Depending on size and contrast of the rectangular iris images, several parameters for iris texture segmentation had to be adjusted accordingly (functions `Segmentiris.m`, `findcircle.m`, and `findline.m` are affected, e.g. the parameters `lpupilradius`, `Upupilradius`, `Hithresh`, `Lowthresh`, etc.) and the size of the resulting polar iris images has been fixed to $240 \times 20$ pixels for all databases. Nevertheless, iris segmentation was not successful in all cases, so we also provide the number of polar iris images per database used subsequently in compression experiments.

**CASIA V1** database[12] consists of 756 images with $320 \times 280$ pixels in 8 bit grayscale .bmp format, 756 polar iris images have been extracted.

**CASIA V3 Interval** database (same URL as above) consists of 2639 images with $320 \times 280$ pixels in 8 bit grayscale .jpeg format, 2638 polar iris images have been extracted.

**MMU** database[13] consists of 457 images with $320 \times 240$ pixels in 24 bit grayscale .bmp format, 439 polar iris images have been extracted.

**MMU2** database (same URL as above) consists of 996 images with $320 \times 238$ pixels in 24 bit colour .bmp format, 981 polar iris images have been extracted.

**UBIRIS** database[14] consists of 1876 images with $200 \times 150$ pixels in 24 bit colour .jpeg format, 614 polar iris images have been extracted.

**BATH** database[15] consists of 1000 images with $1280 \times 960$ pixels in 8 bit grayscale .jp2 (JPEG2000) format, 734 polar iris images have been extracted.

**ND Iris** database[16] consists of 1801 images with $640 \times 480$ pixels in 8 bit grayscale .tiff format, 1626 polar iris images have been extracted.

Figures 1 and 2 provide one example image from each database, the former a rectangular iris image, the latter an extracted polar iris image.

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11 http://www.csse.uwa.edu.au/~pk/studentprojects/libor/sourcecode.html

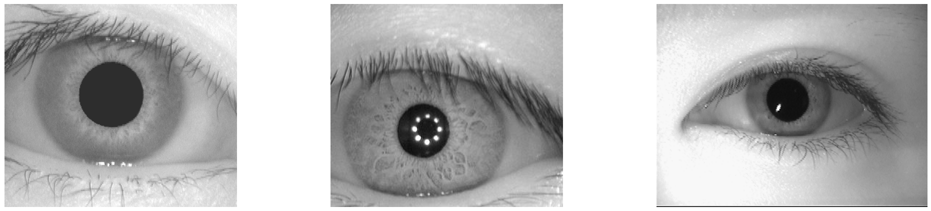
12 http://http://www.cbsr.ia.ac.cn/IrisDatabase.htm/

13 http://pesona.mmu.edu.my/ ccteo/

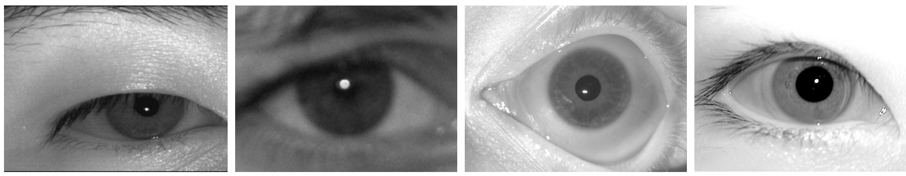
14 http://www.di.ubi.pt/ hugomcp/investigacao.htm

15 http://www.irisbase.com/

16 http://www.nd.edu/ cvrl/CVRL/Data_Sets.html

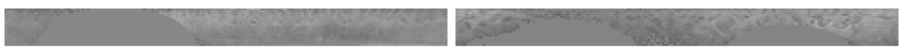


(a) CASIA V1 (b) CASIA V3 (c) MMU

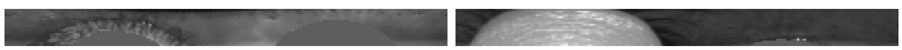


(d) MMU2 (e) UBIRIS (f) BATH (g) ND Iris

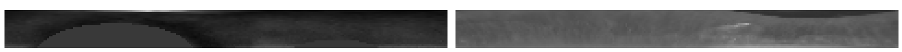
**Fig. 1.** Example rectangular iris images from the used databases.



(a) CASIA V1 (b) CASIA V3 Interval



(c) MMU (d) MMU2



(e) UBIRIS (f) BATH

(g) ND Iris

**Fig. 2.** Example iris polar images from the used databases.

### 3.2 Results

In the subsequent plots, we display the achieved averaged compression ratio on the y-axis, while giving results for different databases or compression algorithms on the x-axis. The small black "error" bars indicate result standard deviation.

When comparing all databases under the compression of a single algorithm, JPEG-LS and PNG provide prototypical results shown in fig. 3 which are very similar to that of most other compression schemes in that there are no significant differences among different databases. Please note that we cannot provide results for SPIHT since the software does not support the low resolution of the polar iris images in y-direction.

For most databases, we result in a compression ratio of about 2.5 or slightly above for JPEG-LS. PNG on the other hand exhibits even less result variability, however, compression ratio does not exceed 1.6 for all databases considered. In the light of the change from JPEG-LS to PNG in the recent ISO/IEC FDIS 19794-6 standard this is a surprising result.

In the following, we provide results for the different databases considered. Fig. 4 shows the results for the CASIA databases. We notice some interesting

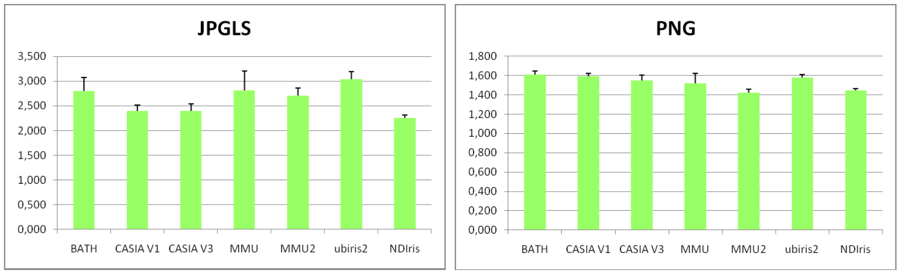



**Fig. 3.** Compression ratios achieved by JPEG-LS and PNG.

effects. First, JPEG-LS is the best algorithm overall. Second, for CASIA V1, ZIP is by far the best performing general purpose compressor while UHA is the best of its group for CASIA V3. Third, we observe suprisingly good results for lossless JPEG while fourth, the results for JPEG XR are almost as poor as those for GIF and PNG.

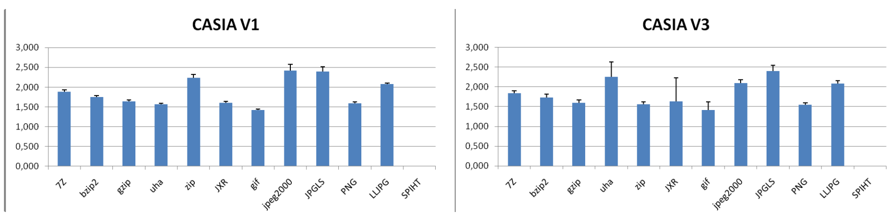



**Fig. 4.** Compression ratios achieved for polar iris images from the CASIA datasets.

As shown in fig. 5, for the MMU (and MMU2 which gives almost identical results) and the ND Iris databases we obtain similar results as for CASIA V1. ZIP is the best general purpose algorithm and JPEG-LS is the best algorithm overall. Also, lossless JPEG performs well. There is an interesting fact to notice. In [2], JPEG2000 has been applied to the MMU dataset in lossless mode with surprisingly good results, however, in this work rectangular iris image data was considered. Here, we do not at all observe specific behaviour of JPEG2000 when applied to the MMU dataset, the results are perfectly in line with those for other datasets.

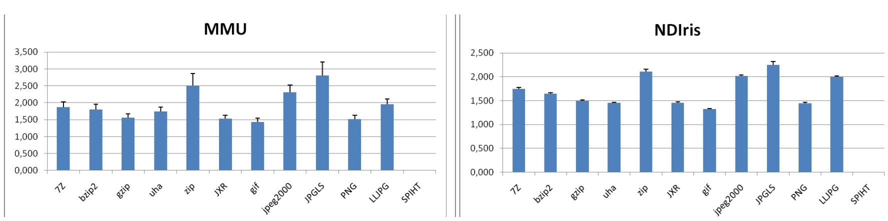



**Fig. 5.** Compression ratios achieved for polar iris images of the MMU and ND Iris datasets.

Similarly, for the BATH and UBIRIS databases JPEG-LS is the best algorithm as shown in fig. 6, JPEG2000 and lossless JPEG perform well. Main difference is again the performance of ZIP and UHA – while for BATH ZIP is the best general purpose algorithm, for the UBIRIS dataset UHA is the second best algorithm overall.

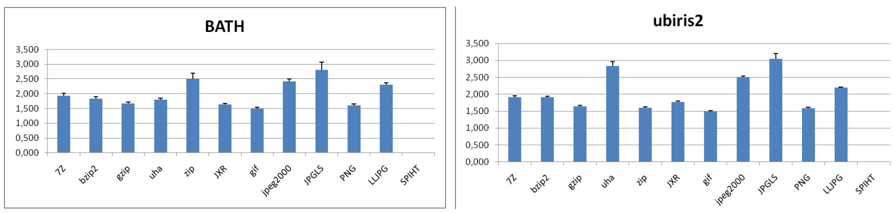



**Fig. 6.** Compression ratios achieved for polar iris images of the BATH and UBIRIS datasets.

Table 1 displays an overview of all databases. For the polar iris images the situation is clear: JPEG-LS is the best algorithm for all datasets (except for CASIA V1 with JPEG2000 ranked first) whereas GIF is always worst. Considering the overall compression ratio achieved, we observe a range of 2.25 - 3.04 for the best techniques. This result taken together with the already small data amount for uncompressed polar iris images makes the required overall data rate very small for this configuration. It is also worth noticing that despite not being specifically designed for image compression purposes, ZIP and UHA excel for several databases, however results vary among different datasets in a non-predictable manner as opposed to the top-performing dedicated image compression schemes.

| | Best | Ratio | Worst | Ratio |
|---|---|---|---|---|
| CASIA V1 | JPEG2000 | 2.42 | GIF | 1.42 |
| CASIA V3 Int. | JPEG-LS | 2.40 | GIF | 1.41 |
| MMU | JPEG-LS | 2.81 | GIF | 1.43 |
| MMU2 | JPEG-LS | 2.71 | GIF | 1.29 |
| UBIRIS | JPEG-LS | 3.04 | GIF | 1.50 |
| BATH | JPEG-LS | 2.80 | GIF | 1.50 |
| ND Iris | JPEG-LS | 2.25 | GIF | 1.32 |

**Table 1.** Best and worst compression algorithm for each database (polar iris images) with corresponding achieved compression ratio.

When comparing the compression ratios to those which can be achieved with lossy techniques (e.g. [5]) we found the relation to be acceptable (considering the advantages of lossless techniques in terms of speed and non-impact on recognition). Polar iris images cannot be compressed that severely using lossy techniques due to the much lower resolution. Therefore, the achieved compression ratios of lossless and lossy schemes differ not too much, such that lossless compression techniques can be a realistic alternative. This is specifically the case for JPEG-LS which exhibits the best compression results and very low computational demands [2, 3].

## 4 Conclusion and Future Work

Overall, JPEG-LS is the best performing algorithm for almost all datasets for polar iris images. Therefore, the employment of JPEG-LS in biometric systems can be recommended for most scenarios which confirms the earlier standardisation done in ISO/IEC 19794. The current choice for a lossless compression scheme in the recent ISO/IEC FDIS 19794-6 standard relying on the PNG format on the other hand seems to be questionable based on the results of this study, at least for polar iris image data. Moreover, as shown in [2], JPEG-LS turns out to be also significantly faster compared to PNG.

We observe compression ratios about 3 and additionally, the ratios found when applying lossy compression schemes to those kind of data are much lower compared to the rectangular iris case due to the much lower resolution. As a consequence, for polar iris images lossless compression schemes can be considered a sensible alternative to lossy schemes in certain scenarios where it is important to limit the computational effort invested for compression.

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