EXPERIMENTAL STUDY ON LOSSLESS COMPRESSION OF BIOMETRIC IRIS 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 lossless JPEG, JPEG-LS, PNG, and GIF, lossless variants of lossy codecs like JPEG2000, JPEG XR, and SPIHT, and a few general purpose compression schemes to rectilinear iris imagery. The results are discussed in the light of the recent ISO/IEC FDIS 19794-6 and ANSI/NIST-ITL 1-2011 standards and the 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. Among other possibilities (e.g. like compressed template storage on IC cards), compression technology may be applied to sample data in two stages of the processing chain in classical biometric recognition for example: First, 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. Second, optional storage of (encrypted) reference data in template databases also may require the data to be handled in compressed form.

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 are often suggested. However, the distortions introduced by compression artifacts may interfere with subsequent feature extraction and may degrade the matching results. In particular, FRR or FNMR will increase (since features of the data of legitimate users are extracted less accurately from compressed data) which in turn affects user convenience and general acceptance of the biometric system. In extreme cases, even FAR or FMR might be affected. 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 especially beneficial in distributed biometric systems often involving weak or low-power sensing devices.

In this work, we experimentally assess the application of several lossless compression schemes to rectilinear iris image sample data (corresponding to IREX KIND1 or KIND3 records) as typically 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 are discussed. Section 4 concludes this work with a discussion and interpretation of the results also related to aspects of required computational effort.

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

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19794-6:2005), Parts 4, 5, and 6 cover fingerprint, face, and iris image data, respectively. In this standard, 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.

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.

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. For example, in [12] we have investigated the impact of JPEG, JPEG2000, SPIHT, PRVQ, and fractal image compression on recognition accuracy of selected fingerprint and face recognition systems. Similarly, [5] also relates JPEG, JPEG2000, and (WSQ) compression rates to recognition performance of some fingerprint and face recognition systems. While most work is devoted to lossy fingerprint compression (e.g. [9, 15]), also lossy compression of face [3] and iris [2, 13, 10, 11, 7, 8] image data have been discussed. A drawback of lossy techniques as compared to lossless ones is their often significantly higher computational demand.

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 [18]. In recent work [21] 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 (only a single dataset, MMU from this current work, has been used). In recent work [6], we have focused on lossless polar iris image data when subjected to an extended set of lossless compression schemes (the same set of compression techniques is used in this work). It has to be pointed out however, that polar iris image data exhibits significant differences as compared to the rectilinear iris data as used in the present study:

1. This type of imagery does no longer conform to the ISO/IEC FDIS 19794-6 standard.
2. Polar iris data are much smaller overall, thus, higher compression ratios may be expected for the rectilinear data.
3. Interpolation techniques are used for transforming the rectilinear data to the polar coordinates [1] used for the polar iris image data. It is not clear in how far this technique affects compression results.

In the subsequent experimental study we will apply an extended set of lossless compression algorithms to image data from several different public iris image databases. The aim is to validate whether the lossless algorithm included in the current versions of the ISO/IEC FDIS 19794-6 and ANSI/NIST-ITL 1-2011 standards actually represent the best solution in terms of compression (or speed).

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 [16]:

Lossless JPEG Image Converter Plus[1] is used to apply lossless JPEG [19], the best performing predictor (compression strength 7) of the DPCM scheme is employed.

JPEG-LS IrfanView[2] 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) [20].

GIF is used from the XN-View software[3] employing LZW encoding.

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

JPEG2000 Imagemagick[4] is used to apply JPEG2000 Part 1, a wavelet-based lossy-to-lossless transform coder [17].

SPIHT lossy-to-lossless zerotree-based wavelet transform codec[5] [14].

JPEG XR FuturixImager[6] is used to apply this most recent ISO still image coding standard, which is based on the Microsoft HD format [4].

[1] `http://www.imageconverterplus.com/`
[2] `http://irfanview.tuwien.ac.at`
[3] `http://www.xnview.com/`
[4] `http://www.imagemagick.org/script/download.php`
[5] `http://www.cipr.rpi.edu/research/SPIHT`
[6] `http://fximage.com/downloads/`

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

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-2 is optimised LZ77 with an arithmetic entropy encoder. The WinUHA software is employed[8].

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.

CASIA V1 database[9] consists of 756 images with 320×280 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.

MMU 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 colour .bmp format.

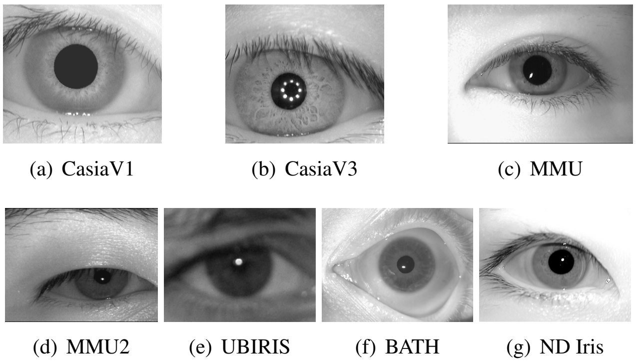
UBIRIS database[11] consists of 1876 images with 200×150 pixels in 24 bit colour .jpeg format.

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.

Figures 1 provides one example image from each database. Depending on the actual database considered, these data correspond to KIND1 or KIND3 IREX records, respectively.

[7] http://www.7-zip.org/download.html
[8] http://www.klaimsoft.com/winuha/download.php
[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) CasiaV1 (b) CasiaV3 (c) MMU

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

Figure 1: Example rectangular iris 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 compression algorithms on the x-axis. The small black "error" bars indicate result standard deviation in order to document result variability.

When comparing all databases under the compression of a single algorithm, JPEG-LS provides a prototypical result shown in Fig. 2 which is very similar to that of all other compression schemes with respect to the relative order of the compression ratios among the different datasets.

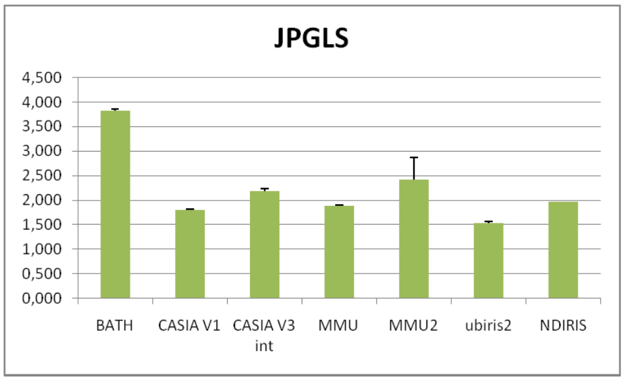


Figure 2: Compression ratios achieved by JPEG-LS.

For most images, we result in a compression ratio of about 2. As it is to be expected, the only original data set with significantly higher resulution also gives higher compression ratio as compared to the others: the images from the Bath database achieve a ratio of more than 3.75. The Ubiris dataset exhibiting the lowest resolution also results in the lowest compression ratio of 1.5.

In Fig. 3 we display the according results for JPEG2000. It is interesting to note that also for dataset MMU, the compression ratio does not even reach 2.0. This significantly contradicts to the results provided in [21], where JPEG2000 excels in compressing iris images of the MMU database.

The most important algorithm with respect to standardisation (according to ISO/IEC FDIS 19794-6 and

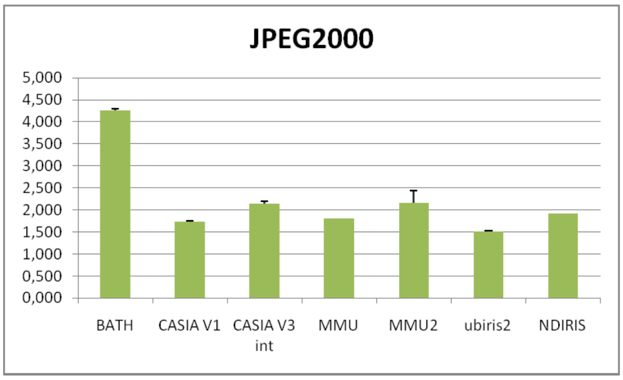


Figure 3: Compression ratios achieved by JPEG2000.

ANSI/NIST-ITL 1-2011) is PNG, the corresponding results are shown in Fig. 4. While the relative performance among the different databases is fairly similar to the results of JPEG-LS and JPEG2000 as seen before, the absolute compression ratios give the impression of being lower in most cases.

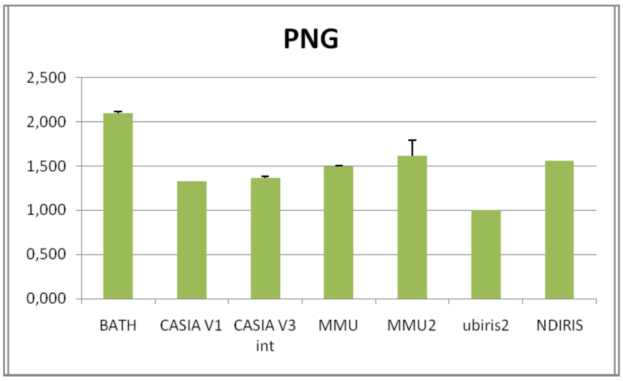


Figure 4: Compression ratios achieved by PNG.

To investigate the relative ranking in more detail, we provide results comparing all compression techniques for each different databases considered in the following. Fig. 5 shows the results for the CASIA databases.

The highest compression ratios obtained are 1.81 and 2.19 for CASIA V1 and V3, respectively. For both datasets, we observe that JPEG-LS, JPEG2000, and SPIHT result in the highest compression rates. With respect to the general purpose compression algorithms, UHA gives the best result similar to the JPEG XR performance. It is particulary interesting to note that PNG delivers the second worst results, clearly inferior to the ratios obtained by the general purpose schemes. Only GIF is even inferior to PNG. The results for UBIRIS and MMU2 are similar to the CASIA datasets (as shown in Figs. 6).

Fig. 7 shows results for the MMU and ND Iris databases where similar overall compression ratios as achieved for the CASIA data have been found. For both datasets UHA provides the best results and moreover, the other general purpose compressors achieve excellent compression ratios.

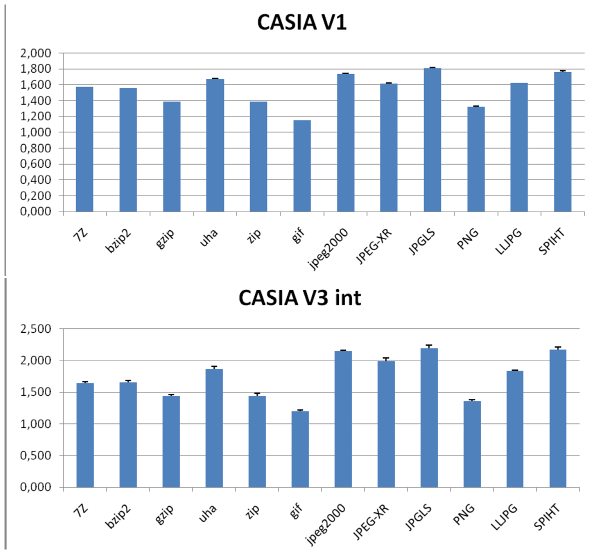


Figure 5: Compression ratios achieved for the CASIA V1 and V3 Interval databases.

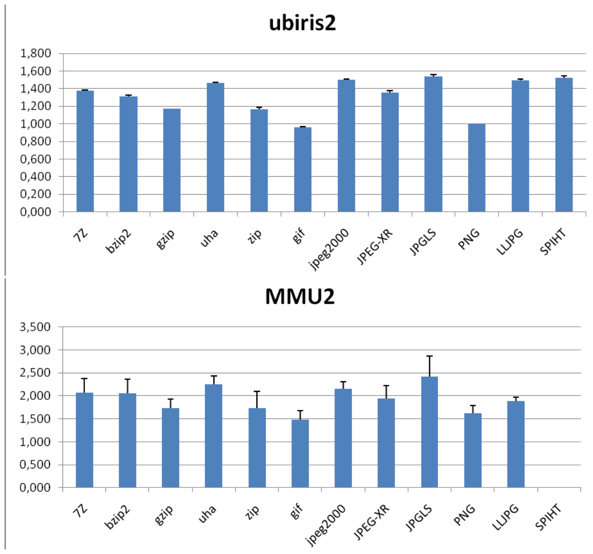


Figure 6: Compression ratios achieved for the UBIRIS and MMU2 databases.

Still GIF and PNG perform worst and JPEG2000, SPIHT, and JPEG-LS are very close to UHA. The performance gap between PNG and the best performing techniques can be considered significant.

For the BATH dataset (see fig. 8), the results are somewhat different, both in terms of overall compression ratios (up to more than 4) and the top performing techniques – in this case, JPEG2000 is best, followed by JPEG-LS and SPIHT. As it is the case for all datasets, UHA is best for the "unspecific" techniques and GIF and PNG are worst performing overall.

The reason for the excellent performance of JPEG2000 in this case is probably due to the higher resolution, but also the original JPEG2000 file format (although converted

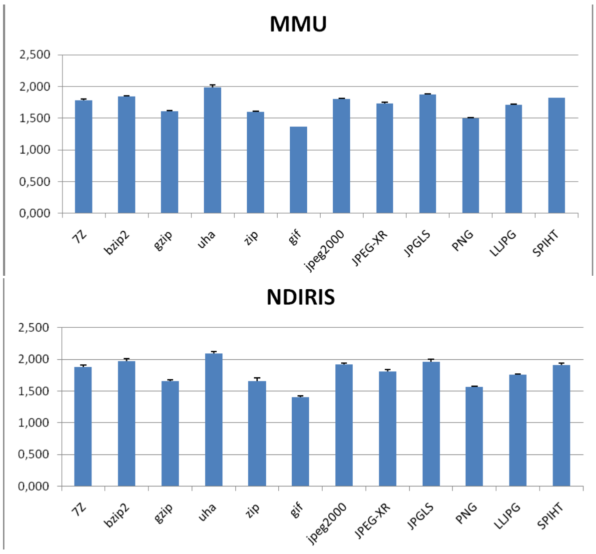


Figure 7: Compression ratios achieved for iris images from the MMU and ND Iris datasets.

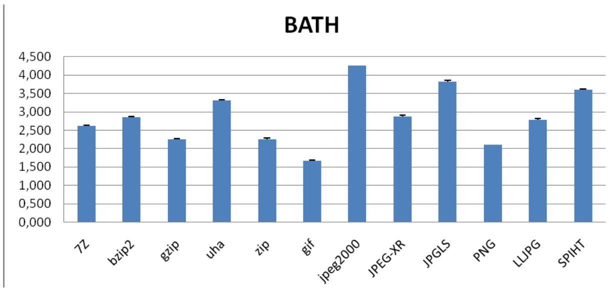


Figure 8: Compression ratios achieved for the BATH dataset.

to .bmp before compression) definitely contributes to this behaviour. Still, the best non-JPEG2000 result (which is JPEG-LS) is almost a factor of 2 better compared to PNG.

Table 1 summarizes the results. It gets immediately clear that GIF is not an option for this kind of data, where for the UBIRIS database even data expansion is observed. The best performing technique overall is JPEG-LS which makes its inclusion in the former ISO/IEC 19794-6 standard a very plausible choice. Also JPEG2000, as included in ANSI/NIST-ITL 1-2011 for lossless compression is among the top performing algorithms. It is surprising to find a general purpose compression scheme like UHA among the best performing techniques, image specific compression schemes would have been expected to be best performing exclusively.

PNG turns out to be consistently the second worst compression scheme for all datasets considered, only superior to GIF. This fact makes the decision to replace JPEG-LS by PNG in the recent ISO/IEC FDIS 19794-6 standard and the inclusion of PNG in ANSI/NIST-ITL 1-2011 highly questionable.

	Best	Ratio	Worst	Ratio
CASIA V1	JPEG-LS	1.81	GIF	1.15
CASIA V3 Int.	JPEG-LS	2.19	GIF	1.20
MMU	UHA	1.99	GIF	1.36
MMU2	JPEG-LS	2.42	GIF	1.47
UBIRIS	JPEG-LS	1.54	GIF	0.96
BATH	JPEG2000	4.25	GIF	1.66
ND Iris	UHA	2.09	GIF	1.40

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

4. Conclusion

Overall, JPEG-LS is the best performing algorithm for most datasets. Therefore, the employment of JPEG-LS in biometric systems can be recommended for most scenarios which confirms the earlier standardisation done in ISO/IEC 19794-6. 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 the PNG format on the other hand does not seem to be very sensible based on the results of this study. Moreover, as shown recently in [21], JPEG-LS turns out to be also significantly faster compared to PNG. The decision to replace JPEG-LS in ISO/IEC FDIS 19794-6, also motivated by the high danger of confusing it with classical JPEG formats, should be reconsidered in the light of our experimental results.

Compared to lossy compression like JPEG2000, the main advantages of lossless schemes are significantly lower computational demand [21] and the guarantee to avoid any impact on recognition performance. For corresponding lossy compression schemes high compression ratios (i.e. 20 and higher) with low impact on recognition performance have been reported (in some cases even improvments have been observed due to denoising effects) [2, 13, 8]. Therefore, it is highly application context dependent, in which environment lossless schemes are actually better suited than their lossy counterparts.

Comparing the overall compression ratios achieved in this study to the ratios obtained from compressing polar iris image data [6], we surprisingly get higher ratios for the polar iris images as compared to the rectangular iris images. This effect is somewhat unexpected since the rectangular images exhbit much higher resolution. However, the texture in the rectangular images is quite inhomogeneous, ranging from background noise to eye lids and the various eye textures, whereas the texture of the polar iris images can be considered as being more homogeneous acreoss the entire image. Additionally, the effects of interpolation as used in the "rubber sheet model [1]" for polar coordinate conversion does lead to smoothed areas which can be compressed better as compared to unprocessed noisy data. These effects explain the (slightly) better results.

References

[1] J. Daugman, "How iris recognition works", *IEEE Transactions on Circiuts and Systems for Video Technology*, 14(1), 2004, pp. 21–30.

[2] J. Daugman and C. Downing, "Effect of severe image compression on iris recognition performance", *IEEE Transactions on Information Forensics and Security*, 3(1), 2008, pp. 52–61.

[3] K. Delac, M. Grgic, and S. Grgic, "Effects of JPEG and JPEG2000 compression on face recognition", In *Proceedings of ICAPR 2005*, volume 3687 of *LNCS*, pp. 136–145. Springer-Verlag, 2005.

[4] F. Dufaux, G. J. Sullivan, and T. Ebrahimi, "The JPEG XR image coding standard", *IEEE Signal Processing Magazine*, 26(6), Nov. 2009, pp. 195–199.

[5] W. Funk, M. Arnold, C. Busch, and A. Munde, "Evaluation of image compression algorithms for fingerprint and face recognition systems", In J. Cole and S. Wolthusen, editors, *Proceedings from the Sixth Annual IEEE Systems, Man and Cybernetics (SMC) Information Assurance Workshop*, pp. 72–78. IEEE Computer Society, June 2006.

[6] K. Horvath, H. Stögner, A. Uhl, and G. Weinhandel, "Lossless compression of polar iris image data", In J. Vitria, J. M. Sanches, and M. Hernandez, editors, *Proceedings of the 5th Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA 2011)*, LNCS. Springer Verlag, 2011. To appear.

[7] R. Ives, B. Bonney, and D. Etter, "Effect of image compression on iris recognition", In *IMTC 2005 – Instrumentation and Measurement Technology Conference*, May 2005.

[8] R. W. Ives, R. P. Broussard, L. R. Kennell, and D. L. Soldan, "Effects of image compression on iris recognition system performance", *Journal of Electronic Imaging*, 17, 2008, pp. 011015, doi:10.1117/1.2891313.

[9] R. Kidd, "Comparison of wavelet scalar quantization and JPEG for fingerprint image compression", *Journal of Electronic Imaging*, 4(1), 1995, pp. 31–39.

[10] M. Konrad, H. Stögner, and A. Uhl, "Custom design of JPEG quantization tables for compressing iris polar images to improve recognition accuracy", In M. Tistarelli and M. Nixon, editors, *Proceedings of the 3rd International Conference on Biometrics 2009 (ICB'09)*, volume 5558 of *LNCS*, pp. 1091–1101. Springer Verlag, 2009.

[11] G. Kostmajer, H. Stögner, and A. Uhl, "Custom JPEG quantization for improved iris recognition accuracy", In D. Gritzalis and J. Lopez, editors, *Emerging Challenges for Security, Privacy and Trust. Proceedings of the 24th IFIP International Information Security Conference 2009 (IFIP SEC'09)*, volume 297 of *IFIP AICT*, pp. 76–86. Springer Verlag, May 2009.

[12] A. Mascher-Kampfer, H. Stögner, and A. Uhl, "Comparison of compression algorithms' impact on fingerprint and face recognition accuracy", In C. Chen, D. Schonfeld, and J. Luo, editors, *Visual Communications and Image Processing 2007 (VCIP'07)*, number 6508 in Proceedings of SPIE, pp. 650810–1 – 65050N–10, San Jose, CA, USA, Jan. 2007. SPIE.

[13] S. Matschitsch, M. Tschinder, and A. Uhl, "Comparison of compression algorithms' impact on iris recognition accuracy", In S.-W. Lee and S. Li, editors, *Proceedings of the 2nd International Conference on Biometrics 2007 (ICB'07)*, volume 4642 of *LNCS*, pp. 232–241. Springer Verlag, 2007.

[14] A. Said and W. A. Pearlman, "A new, fast, and efficient image codec based on set partitioning in hierarchical trees", *IEEE Transactions on Circuits and Systems for Video Technology*, 6(3), June 1996, pp. 243–249.

[15] B. G. Sherlock and D. M. Monro, "Optimized wavelets for fingerprint compression", In *Proceedings of the 1996 International Conference on Acoustics, Speech and Signal Processing (ICASSP'96)*, Atlanta, GA, USA, May 1996.

[16] J. Storer, *Image and Text Compression*, The Kluwer international series in engineering and computer science, Kluwer Academic Publishers Group, Boston, 1992.

[17] D. Taubman and M. Marcellin, *JPEG2000 — Image Compression Fundamentals, Standards and Practice*, Kluwer Academic Publishers, 2002.

[18] J. Thärna, K. Nilsson, and J. Bigun, "Orientation scanning to improve lossless compression of fingerprint images", In J. Kittler and M. Nixon, editors, *Proceedings of AVBPA*, volume 2688 of *LNCS*, pp. 343–350. Springer Verlag, 2003.

[19] G. Wallace, "The JPEG still picture compression standard", *Communications of the ACM*, 34(4), 1991, pp. 30–44.

[20] M. Weinberger, G. Seroussi, and G. Sapiro, "Lossless image compression algorithm: Principles and standardization into JPEG-LS", *IEEE Transactions on Image Processing*, 9(8), Aug. 2000, pp. 1309–1324.

[21] G. Weinhandel, H. Stögner, and A. Uhl, "Experimental study on lossless compression of biometric sample data", In *Proceedings of the 6th International Symposium on Image and Signal Processing and Analysis, ISPA '09*, Salzburg, Austria, Sept. 2009.