Investigation of Better Portable Graphics Compression for Iris Biometric Recognition

Heinz Hofbauer*, Christian Rathgeb†, Johannes Wagner†, Andreas Uhl* and Christoph Busch†
*Multimedia Signal Processing and Security Lab, University of Salzburg, Austria
{hhofbaue,uhl}@cosy.sbg.ac.at
†da/sec - Biometrics and Internet Security Research Group, Hochschule Darmstadt, Germany
{christian.rathgeb,johannes.wagner,christoph.busch}@cased.de

***Abstract*—In this paper we present the very first study on the effectiveness of the recently proposed Better Portable Graphics (BPG) image compression algorithm in the context of iris recognition. Original and pre-processed iris images of the IITDv1 iris database are compressed at various reasonable bitrates and the impact of BPG on recognition accuracy is estimated in a bilateral and unilateral compression scenario.**

In experiments we found that, compared to well-established image compression standards recommended for biometric data interchange, JPEG and JPEG 2000, BPG generally reveals the least impact on the recognition accuracy of two conventional feature extraction techniques. In addition, we observe that iris segmentation is least affected when employing BPG compression. Consequentially, we identify BPG as an adequate choice for image compression in iris recognition.

I. Introduction

Biometrics in particular, technologies of iris recognition [1] represent a rapidly evolving field of research where large-scale biometric systems are already deployed, *e.g.* the Indian Aadhaar project [2]. Within such deployments efficient storage and rapid transmission of biometric records are a driving implementation factor, especially for biometric recognition in environments with low-powered mobile sensors or smart-cards. In order to retain vendor neutrality, the International Organization for Standardization (ISO/IEC) specifies iris biometric data to be recorded and stored in (raw) image form rather than in extracted templates, *i.e.* iris-codes [3]. Existing studies [4], [5], [6] confirm the applicability of lossy image compression in iris biometric systems, recommending the JPEG 2000 standard for iris biometric image compression, which generally outperforms JPEG in terms of PSNR rate-distortion behaviour [3]. However, recently it has been shown that rate-distortion performance represents a poor predictor for biometric performance (recognition accuracy). In particular, for conventional iris segmentation techniques the use of JPEG compression, which maintains clear edges that assist iris texture boundary localization, has been found to reveal superior results compared to JPEG 2000 [7].

More recently, the H.265/HEVC-based image compression algorithm BPG [8] has been proposed showing promising compression results at minimal human visual perceptible image quality degradation. In this work we examine the usefulness of BPG in the context of iris image compression. In two different scenarios, compression of pre-processed iris textures and compression of original (cropped) iris images, BPG is compared against JPEG and JPEG 2000 at rates ranging from 1.0 to 0.3 bits per pixel (bpp). In experiments on the uncompressed IITDv1 iris database, the impact of compression algorithms on the performance of two conventional iris recognition systems is evaluated. Considering both cases, bilateral as well as unilateral compression of iris images, we identify BPG as a suitable candidate for iris image compression generally impacts the recognition ratio the least in both scenarios, especially at low compression rates.

This paper is organized as follows: section II briefly summarizes related works. The experimental setup of this study is described in section III and obtained results are presented in section IV. Finally, conclusions are drawn in section V.

II. Related Work

Focusing on standardization of iris image formats, the ISO/IEC IS 19794-6 [3] represents the most relevant standard. Supported by studies conducted in the NIST Iris Exchange program [9], JPEG 2000 is recommended exclusively for lossy compression in iris data exchange (IREX records). Apart from standardization numerous studies dealing with image compression in iris recognition have been conducted: the very first study is provided by Rakshit *et al.* [4]. They show, that moderate compression of up to 0.5 bpp (bits/pixel) using the JPEG 2000 codec improves recognition accuracy. Their 2156 images dataset, however, refers to CASIA Version 1 data, which does not allow for any conclusions on segmentation impact. Matschitsch *et al.* [10] compare a variety of different compression algorithms (JPEG, JPEG 2000, zero-tree based SPIHT, vector quantization PRVQ, and fractal compression FRAC) resulting in JPEG 2000, SPIHT and PRVQ being almost equally well suited for iris compression. Daugman and Downing [5] report, that for a file size of 2000 bytes (1:150 compression ratio) bit flips are caused for only 2-3% of bits in extracted templates, while recognition accuracy is maintained using 1425 images of the ICE database. In their evaluation they did not only employ compression on cropped original images, but also segmentation-assisted cropped and masked (IREX K7) images. Grother [6] surveys existing approaches and compares JPEG and JPEG 2000 to give a quantitative support to the revision of the ISO/IEC IS 19794-6 [3] including the cropped format (IREX K3), masked and cropped image format (IREX K7), and unsegmented polar format (IREX K16). The author examines the effect of iris radius, limits of cropping, horizontal and vertical margins, eye lashes, and algorithmic resistance to compression. Ives *et al.* [11] observe, that a compression of normalized textures has no significant impact on recognition accuracy (compression ratio until 1:100 is feasible). The authors argue, that compression processes may add unique patterns assisting the recognition process.

Conventional image compression algorithms are either optimised with respect to human perception (*e.g.* the JPEG default quantisation (Q-)table) or with respect to rate-distortion criteria (*e.g.* Tier-2 coding in JPEG 2000). For applications in pattern recognition, optimisation with respect to these criteria is not necessarily the optimal solution. In [12] the JPEG Q-table is tuned for application in the pattern recognition context by emphasising middle and high frequencies and discarding low frequencies, which has already been considered in face recognition [13], leading to improved recognition performance. Focusing on iris biometrics, optimisation of JPEG 2000 Part 2 wavelet packet decomposition structures with respect to optimising iris recognition accuracy which provides better results compared to rate-distortion optimised wavelet packet structures [14]. Further, in [7] it has been shown, that while JPEG 2000 is recommended for compressing iris images [3], [5], the use of JPEG compression yields better segmentation results of cropped iris images (IREX K3), maintaining clearer boundaries between the iris texture and pupil and sclera, respectively, compared to JPEG 2000 and JPEG XR compression.

The BPG format [8] is based on the H.265/HEVC video format and a valid HEVC bitstream can be reconstructed from the BPG in case an non modifiable hardware decoder is present. The H.265/HEVC video format is rather complex and there is no single reason for the improvement over the H.264/AVC video codec but rather a large collection of small improvements. The H.265/HEVC format is standardised in [15] and an overview over the various techniques used and improvements over H.264/AVC is given in [16].

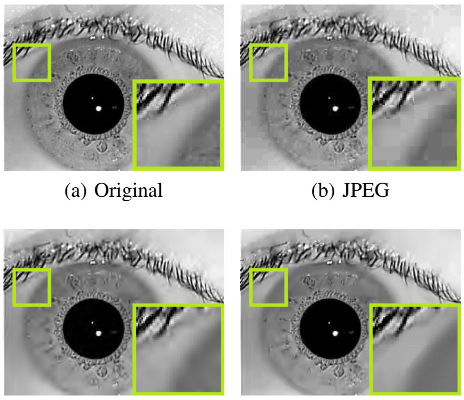
The H.265/HEVC subset that comprises BPG was chosen to support a wide variety of features, e.g. animation support, as well support for all features which are present in JPEG, *e.g.* colorspaces, as well as the extended JPEG standard (JPEG XT) [17], *e.g.* higher dynamic range and lossless compression. The main improvement over the JPEG standard in terms of coding efficiency can be reduced to the smaller block size, combined with an adaptive decomposition quadtree, and intra frame prediction. Focusing on computational complexity, BPG encoding requires slightly more time compared to JPEG, while it still operates in real time (fraction of a second) for iris images considered in this work.

III. Experimental Setup

A. Database, Segmentation and Recognition

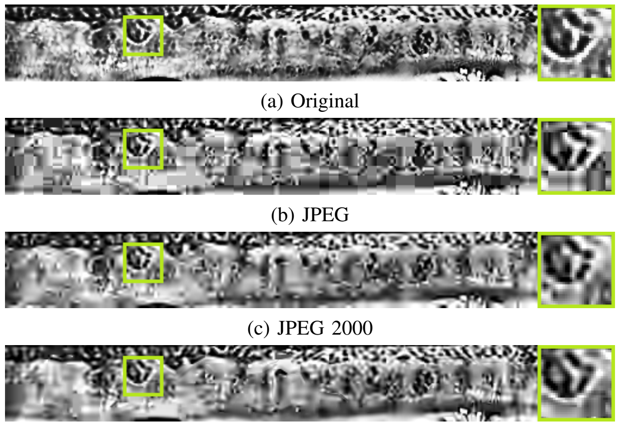
Experiments are carried out using the IITD Iris Database version 1.0 which comprises 2,240 NIR iris images from 224 different subjects. For each subject the first five iris images were acquired from the left eye while the remaining five images were acquired from the right eye, yielding a total number of 448 classes. Original images are sized 320×240 pixels and take 77.11kB in uncompressed form, a sample image is depicted in figure 1a. Unrolled and normalized iris texture images are sized 512×64 pixels and take 34.58kB in uncompressed form, a sample image is depicted in figure 2a.

We employ (custom) implementations of one segmentation algorithm and two feature extraction techniques publicly available in the USIT software [18]: the Daugman-like [1] Contrast-Adaptive Hough Transform (CAHT) [19] for segmentation, the feature extraction of Ma *et al.* [20], based on dyadic wavelet transforms, and the feature extraction of Masek [21] based on 1D Log-Gabor filters. For further details on these implementations the reader is referred to [18].



(a) Original (b) JPEG (c) JPEG 2000 (d) BPG

Fig. 1. Original version and compressions at 0.3 bpp for `001-01.bmp` of IITD-v1.



(a) Original (b) JPEG (c) JPEG 2000 (d) BPG

Fig. 2. Original version and compressions at 0.3 bpp for texture image of figure 1a.

For a comparison of compression performance between JPEG, JPEG 2000 (as J2K) and BPG see table I. The comparison is performed on the original cropped eye images and iris texture images (as extracted by the CAHT [18] algorithm). We do not consider segmentation-assisted cropped and masked images as suggested in [5] since those already require a segmentation of the iris, *i.e.* we directly employ pre-processed

TABLE I. PSNR[dB] Comparison of JPEG, JPEG2000 and BPG for eye and texture images. Entries are given as *PSNR eye*|*PSNR texture* for a compression method (row) and fixed Bits per pixel (column).

format	Bits per pixel 0.3	0.5	0.7	0.9	1.0
JPEG	25.8 |18.0	28.1 |20.1	29.8 |21.8	31.2 |23.1	31.8 |23.7
J2K	27.0 |18.7	29.7 |21.0	31.9 |22.7	33.9 |24.3	34.8 |25.0
BPG	29.0 |20.2	32.0 |22.5	35.0 |24.3	37.8 |25.9	39.2 |26.6

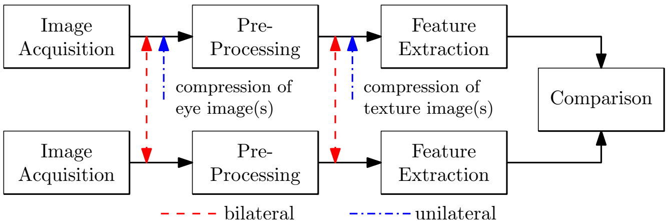


Fig. 3. Overview of considered evaluation framework.

texture images. For JPEG and BPG compression we iteratively configure quality parameters in order to obtain desired bitrates using the *convert* tool and the BPG encoder available at [8], for JPEG 2000 we use the *JJ 2000* encoder [22]. In [23] effects of JPEG-XR compression on iris recognition are examined revealing similar results to JPEG 2000, *i.e.* we do not consider JPEG-XR in our study. It can be observed that the BPG compression performance in terms of visual quality outperforms the JPEG and JPEG 2000 formats.

B. Compression Scenarios

In experiments we consider two scenarios: (1) compression of original iris images and (2) compression of iris texture images, depicted in figure 3. In the first scenario, which represents the most relevant case, the iris image is directly compressed after acquisition. If biometric sensors do not have the ability to conduct pre-processing it may be necessary to apply lossy image compression to the original eye image for volume reduction of data to be transmitted. Sample images for both scenarios are shown in figure 1b-1d and figure 2b-2d. Further, we evaluate both scenarios using bilateral and unilateral compression, which means that both or only one of the images to be compared are compressed, respectively.

IV. Experimental Evaluation

A. Compression of Iris Textures

In a first test, which is given in table IIIa and figure 4a, the bilateral case is evaluated. The baseline is the result of the uncompressed comparison. The results show that the performance for all compression types is quite good and comparable. The errors (in terms of EER difference to the baseline) are minor, less than 0.1% for Masek and less than 0.15% for Ma. We restrict to report EERs as single point of measurement since the large number of compression scenarios hinders a comparisons in terms of ROC curves.

However, the compression of the newly acquired texture requires additional computation and might impact the responsiveness of a biometric system. Optimally the unilateral comparison shows the same performance as the bilateral comparison, in which case the additional compression step can be skipped. Table IIIb and figure 4b show the results of the bilateral comparison. Only BPG shows a similar behaviour in the bilateral case. The JPEG and JPEG 2000 compression influences the results and lead to a different behaviour. Interestingly, the compression with JPEG and JPEG 2000 increases the performance for the tested feature extraction methods. However, that the compression results in an improvement, can not be guaranteed for other feature extraction methods, and thus should be take as a sign of change to the baseline rather than an improvement. Especially since the compression of the

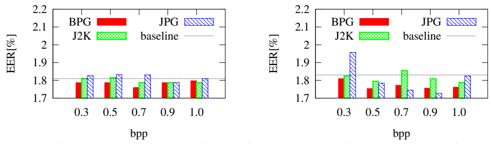
TABLE II. EERs of compressed iris texture images.

Masek; baseline 1.8097				Ma; baseline 1.8300			
bpp	BPG	J2K	JPG	bpp	BPG	J2K	JPG
0.3	1.79	1.81	1.83	0.3	1.81	1.82	1.96
0.5	1.79	1.81	1.83	0.5	1.75	1.79	1.78
0.7	1.76	1.79	1.83	0.7	1.77	1.86	1.74
0.9	1.79	1.79	1.79	0.9	1.76	1.81	1.73
1.0	1.80	1.79	1.81	1.0	1.76	1.79	1.82

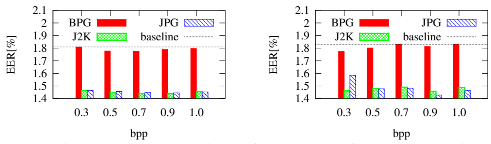
(a) Bilateral comp. of Masek (left) and Ma (right)

Masek; baseline 1.8097				Ma; baseline 1.8300			
bpp	BPG	J2K	JPG	bpp	BPG	J2K	JPG
0.3	1.81	1.47	1.47	0.3	1.77	1.46	1.59
0.5	1.78	1.45	1.46	0.5	1.80	1.48	1.48
0.7	1.78	1.44	1.45	0.7	1.83	1.49	1.48
0.9	1.79	1.44	1.45	0.9	1.81	1.46	1.43
1.0	1.80	1.45	1.45	1.0	1.83	1.49	1.46

(b) Unilateral comp. of Masek (left) and Ma (right)



(a) Bilateral compression of Masek (left) and Ma (right)



(b) Unilateral compression of Masek (left) and Ma (right)

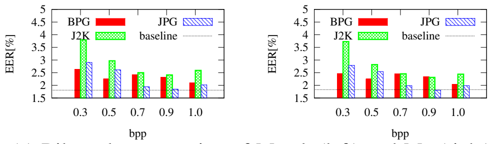
Fig. 4. EERs of compressed iris texture images.

stored textures is final and can not be reversed in case it would impact a feature extraction method aversely.

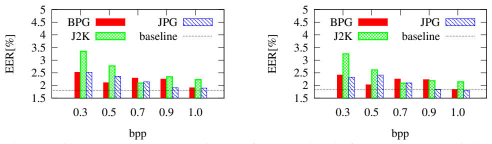
B. Compression of Original Images

Similarly to the texture case the question then is in what way the unilateral or bilateral compression influences the result of the biometric system. Compression is even more important in this case since the original eye images are larger and take up more space than the texture images. Also note that the effects that were seen in the texture compression case will also influence the original image case, since the image compression will also result in a compression of the iris texture.

Evaluation results are shown in table IVb and figure 5b for the unilateral case and in table IVa and figure 5a for the bilateral case. The first fact to notice is that the overall performance impact of compression is higher than with texture image compression since the segmentation is now also performed on the compressed images and can introduce errors. JPEG and JPEG 2000 show a similar behaviour as with the textured images, in that the unilateral case is different than the bilateral case, and that again it seems to improve the EER. As was the case with texture images the BPG compression shows a more stable behaviour, being roughly equal in performance for both unilateral and bilateral compression. In this scenario BPG and JPEG outperform JPEG 2000 and while JPEG shows better performance in the low compression tests, BPG performs better for higher compression.



(a) Bilateral compression of Masek (left) and Ma (right)



(b) Unilateral compression of Masek (left) and Ma (right)

Fig. 5. EERs of compressed original eye images.

TABLE III. EERS OF COMPRESSED ORIGINAL EYE IMAGES.

Masek: baseline 1.8097				Ma: baseline 1.8300			
bpp	BPG	J2K	JPG	bpp	BPG	J2K	JPG
0.3	2.63	3.79	2.90	0.3	2.47	3.73	2.79
0.5	2.25	2.97	2.61	0.5	2.25	2.82	2.54
0.7	2.42	2.50	1.94	0.7	2.46	2.46	1.99
0.9	2.32	2.41	1.85	0.9	2.34	2.31	1.81
1.0	2.10	2.59	2.01	1.0	2.03	2.44	1.99

(a) Bilateral comp. of Masek (left) and Ma (right)

Masek; baseline 1.8097				Ma; baseline 1.8300			
bpp	BPG	J2K	JPG	bpp	BPG	J2K	JPG
0.3	2.52	3.35	2.52	0.3	2.41	3.25	2.32
0.5	2.11	2.77	2.36	0.5	2.03	2.62	2.41
0.7	2.29	2.10	2.14	0.7	2.26	2.09	2.10
0.9	2.25	2.34	1.91	0.9	2.23	2.19	1.85
1.0	1.91	2.23	1.90	1.0	1.85	2.15	1.81

(b) Unilateral comp. of Masek (left) and Ma (right)

V. CONCLUSION

We presented the very first studies on the usefulness of BPG compression in iris biometrics. Comparing the BPG format to JPEG and JPEG 2000 in different compression scenarios, including bilateral and unilateral compression, we conclude that BPG is suitable candidate for image compression in iris recognition, especially for low bitrates and for compressing original images rather than texture images, where the former case has more practical relevance. Further, we identify the fact that the BPG encoder/ decoder is released under the BSD license a cutting-edge prerequisite in order to potentially establish BPG compression in the area of biometrics.

ACKNOWLEDGEMENTS

This work was partially supported by the European FP7 FIDELITY project (SEC-2011-284862), the Center for Advanced Security Research Darmstadt (CASED) and the Austrian Science Fund, project no. P26630.

REFERENCES

[1] J. Daugman, "How iris recognition works," *IEEE Trans. Circ. and Syst. for Video Techn.*, vol. 14, no. 1, pp. 21–30, 2004.

[2] Unique Identification Authority of India, "Aadhaar project," http://uidai.gov.in/, retrieved Jan., 2015.

[3] I. O. for Standardization, *ISO/IEC 19794-6:2011. Information technology – Biometric data interchange formats – Part 6: Iris image data*, 2011.

[4] S. Rakshit and D. M. Monro, "An evaluation of image sampling and compression for human iris recognition," *IEEE Trans. Inf. Forensics and Sec.*, vol. 2, pp. 605–612, 2007.

[5] J. Daugman and C. Downing, "Effect of severe image compression on iris recognition performance," *IEEE Trans. Inf. Forensics and Sec.*, vol. 3, pp. 52–61, 2008.

[6] P. Grother, "Quantitative standardization of iris image formats," in *Proc. of the Biometrics and Electronic Signatures (BIOSIG 2009)*, ser. LNI, 2009, pp. 143–154.

[7] C. Rathgeb, A. Uhl, and P. Wild, "Effects of severe image compression on iris segmentation performance," in *Proc. of the Int'l Joint Conf. on Biometrics (IJCB'14)*, 2014, pp. 1–6.

[8] F. Bellard, "BPG image format," http://http://bellard.org/bpg, retrieved Jan., 2015.

[9] National Institute of Standards and Technology, "NIST Iris Exchange program," http://iris.nist.gov/irex/, retrieved Jan., 2015.

[10] S. Matschitsch, M. Tschinder, and A. Uhl, "Comparison of compression algorithms' impact on iris recognition accuracy," in *Proc. of the 2nd Int'l Conf. on Biometrics (ICB 2007)*, ser. LNCS, 4642, 2007, pp. 232–241.

[11] R. W. Ives, D. A. Bishop, Y. Du, and C. Belcher, "Iris recognition: The consequences of image compression," *EURASIP J. on Adv. in Signal Processing*, vol. 2010, p. 9 pages, 2010.

[12] M. Chen, S. Zhang, and M. Karim, "Modification of standard image compression methods for correlation-based pattern recognition," *Optical Engineering*, vol. 43, no. 8, pp. 1723–1730, 2004.

[13] G.-M. Jeong, C. Kim, H.-S. Ahn, and B.-J. Ahn, "JPEG quantization table design for face images and its application to face recognition," *IEICE Trans. on Fundamentals of Electronics, Comm. and Computer Science*, vol. E69-A, no. 11, pp. 2990 – 2993, 2006.

[14] J. Hämmerle-Uhl, M. Karnutsch, and A. Uhl, "Evolutionary optimisation of JPEG2000 Part 2 wavelet packet structures for polar iris image compression," in *Proc. of the 18th Iberoamerican Con. on Pattern Recognition (CIARP'13)*, 2013, pp. 391–398.

[15] ITU-T H.265, "High efficiency video coding," Apr. 2013, http://www.itu.int/rec/T-REC-H.265-201304-I, retrieved Jan., 2015.

[16] M. Budagavi, A. Fuldseth, G. Bjontegaard, V. Sze, and M. Sadafale, "Core Transform Design for the High Efficiency Video Coding (HEVC) Standard," *IEEE Journal of Selected Topics in Signal Processing*, 2013.

[17] T. Richter, "On the standardization of the JPEG XT image compression," in *Picture Coding Symposium (PCS), 2013*, Dec 2013, pp. 37–40.

[18] C. Rathgeb, A. Uhl, and P. Wild, *Iris Recognition: From Segmentation to Template Security*, ser. Advances in Information Security. Springer Verlag, 2013, vol. 59.

[19] J. Hämmerle-Uhl, E. Pschernig, and A.Uhl, "Cancelable iris biometrics using block re-mapping and image warping," *In Proc. of the Information Security Conf. 2009 (ISC'09) LNCS: 5735*, pp. 135–142, 2009.

[20] L. Ma, T. Tan, Y. Wang, and D. Zhang, "Efficient iris recognition by characterizing key local variations," *IEEE Trans. Image Proc.*, vol. 13, no. 6, pp. 739–750, 2004.

[21] L. Masek and P. Kovesi, "MATLAB Source Code for a Biometric Identification System Based on Iris Patterns," 2003, retrieved May, 2012. [Online]. Available: http://www.csse.uwa.edu.au/~pk/studentprojects/libor/sourcecode.html

[22] D. Engel, "JJ 2000," http://www.wavelab.at/sources/, retrieved Jan., 2015.

[23] K. Horvath, H. Stögner, and A. Uhl, "Effects of jpeg xr compression settings on iris recognition systems," in *Proc. of the 14th Int'l Conf. on Comp. Anal. of Images and Patt.*, ser. LNCS, 6855, 2011, pp. 73–80.