P. Wild, S. Stolc, K. Valentin, F. Daubner and M. Clabian. Compression Effects on Security Document Images. In *Proceedings of the 2016 European Intelligence and Security Informatics Conference (EISIC'16)*, 4 pages, Uppsala, Sweden, August 17–19, 2016. © IEEE. The original publication will be available at http://www.ieeexplore.com.

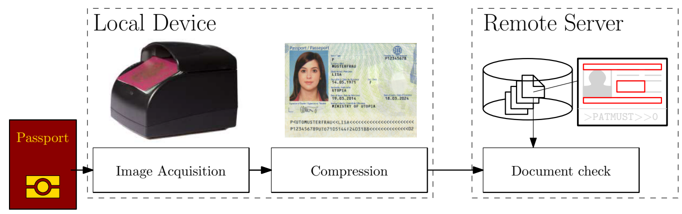
Compression Effects on Security Document Images

Peter Wild, Svorad Štolc, Kristián Valentín, Franz Daubner and Markus Clabian
Digital Safety and Security Department
AIT Austrian Institute of Technology, Donau-City-Str. 1, 1220 Vienna, Austria
Email: {peter.wild, svorad.stolc, kristian.valentin, franz.daubner, markus.clabian}@ait.ac.at

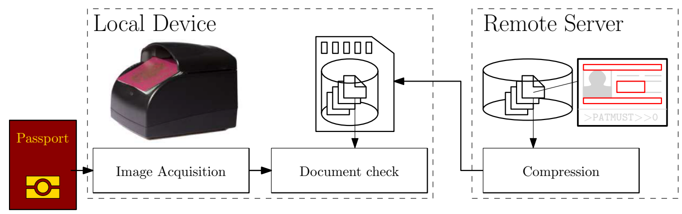
***Abstract*—Compression effects for security documents can have an important impact on optical document inspection in border control: High-frequency information, usually suffering from compression artefacts, is difficult to reproduce and an inherent security feature. Where the processing of uncompressed data is not an option, e.g., for mobile equipment with limited processing bandwidth or large template databases of prototype security regions, it is useful to study compression properties of this particular type of data. We present an evaluation of three state-of-the-art lossy image compression standards applied to acquisitions of passports from nine security document readers in VIS, UV, and IR spectra. In particular, we tested JPEG (ISO/IEC 10918-1, 1994), JPEG-XR (ISO/IEC 29199-2, 2010), and JPEG 2000 (ISO/IEC 15444-1, 2000). Results show that JPEG-XR outperforms the other approaches for security documents across the range of tested devices and spectra.**

I. Introduction

Severe lossy compression of acquired image data has been shown to have a (negative) impact on biometric authentication (e.g., compressed fingerprints or face data [2]) and likely this is also true for document authentication. Lossy image compression may introduce local artefacts corrupting text or optical security features (e.g., microprints), hence should be avoided where possible. However, there are cases, where compressed storage of security documents (or patches thereof) is beneficial. Studying the impact of compression in document security is motivated by two different scenarios, see Fig. 1. In the first use case, the reader is employed as a mobile sensor. Input images of travel documents are acquired but not processed locally. This scenario is especially interesting for next generation mobile or low-power readers, devices lacking the ability to conduct optical security checks for power reasons (e.g., mobile sensor) and/or security reasons (e.g., mobile phone with validation service). If document checks are to be conducted remotely, bandwidth consumption should be minimized. The second use case employs a compact template database of security features. It is desirable to limit the size of such recorded templates of known security features. For the comparison of security elements, templates are retrieved from the database and compared with the presented (uncompressed) document. Ideally, templates are stored in compressed form allowing compact storage on mobile devices. Indeed the number of such "templates" is large and a high level-of-detail on individual templates is desirable. While the storage of feature vectors rather than image patches would be an alternative, for exchange purposes access to image data is beneficial (e.g., compare with biometric data exchange ISO/IEC 19794).



Scenario A: Compression of data for trusted remote verification.



Scenario B: Compressed template database for local verification.

Fig. 1: Compression use cases in optical document inspection.

There are two central questions at the heart of the contribution of this study: (1) "Up to which bitrate can passport data be compressed using lossy compression techniques without severely affecting image quality?" (2) "Which compression algorithm is most efficient for passports?" Furthermore, as a passport's visible data page contains security features which are sensed in different wavelengths, it is interesting to see the impact of compression on multiple spectra. As a by-product of finding answers to these questions, we also compare different document readers with regards to the compression algorithms' ability to impact on loss of detail with increasing compression rate using the same set of documents. High loss of detail for a particular reader indicates the presence of high-frequency information and can be interpreted in connection with the readers optical resolution and noise level profile analysed in a separate experiment [7]. Especially for interoperability of document readers it is interesting to see, how compression affects different readers, being aware of potential double compression effects and the impact of varying recording conditions. Furthermore, multispectral acquisition including visible (VIS), near infrared (NIR) and ultra-violet (UV) spectra, indicates rather different characteristics to be reflected in the choice of a valid compression rate preserving security properties.

The paper is organised as follows: Section II introduces related work, followed by an overview of compression algorithms. Results of the conducted experiment are reported in Section III. Finally, Section IV outlines the conclusion.

II. Compression in Document Inspection

There is currently no public study known to the authors dedicated to compressing security documents. However, automated border control and self-service electronic gates have emphasized the need for more transparent analysis. The few available research works in border control focus on face compression and storage on a document's barcode [1] enhancing document authentication, and passport photo compression as a main target [4]. Watermarking has been suggested [6] for detecting tampering of image regions in security documents, embedding information in the integer wavelet IWT domain and DCT domain, and results have shown to be robust against JPEG compression. If information is to be embedded in images (e.g., for authentication purposes, etc.), compression rates have to be selected carefully in order not to destroy watermarking information. Further research has been conducted for an efficient trade-off between embedding and compression rates, esp. for JPEG and JPEG 2000 compression [8].

This study evaluates well-known compression algorithms' behaviour on passport images. Different recording modes (VIS, NIR, UV) are taken into account, see Fig. 2 and the following compression algorithms are employed:

- **JPEG** (ISO/IEC IS 10918-1) compresses images using 2D discrete cosine transform (on 8×8 blocks) and quantization, using run-length with Huffman / Arithmetic coding. We use ImageMagick for this task, employing binary search for each image achieving a target compression ratio in the interval [0.1,1] bits per pixel channel (bpp).
- **JPEG 2000** (also: JPEG-2K) is the next-generation wavelet-based compression standard (ISO/IEC IS 15444-1) lacking the traditional block artefacts of JPEG and coming with an explicit compression rate control and context-dependent binary arithmetic coding of bit-planes. ImageMagick's convert tool (OpenJPEG) is used (jp2:rate parameter for size control).
- **JPEG-XR** is a 4×4 LBT block-based algorithm based on the Photo Core Transformation (similar to DCT) with inter-block coefficient prediction and Hadamard Transformation, proposed by Microsoft's HD Photo. While perceived as being between JPEG 2000 and JPEG in terms of PSNR performance, the employed reference software (Microsoft's ISO/IEC IS 29199-5) is fast.

Fig. 2: Same specimen document (left-to-right: VIS, NIR, histogram-stretched UV) acquired using different readers.

III. Experimental Results

For experiments we used the passport subset of AIT's collected FastPass document reader challenge database [7] containing 1116 passport images from 12 countries acquired with 9 different document readers (see Table I). Where supported, glare reduction feature was activated for the acquisition.

Note that reader-specific results are anonymized. All images were normalized (bilinear interpolation) with regards to 400 DPI optical sensor resolution. We compressed entire passport images choosing the parameter setup achieving closest distance with regards to a target file size in order to ensure comparability of results. Target file size was chosen to reflect a bit rate of 0.1 bits per pixel (bpp, for each channel) to 1.0 bpp with a step size of 0.1 bpp. Results are reported in terms of Peak-Signal-to-Noise Ratio (PSNR):

$$PSNR = 10\log_{10}\left(\frac{MAX^2}{MSE}\right) \tag{1}$$

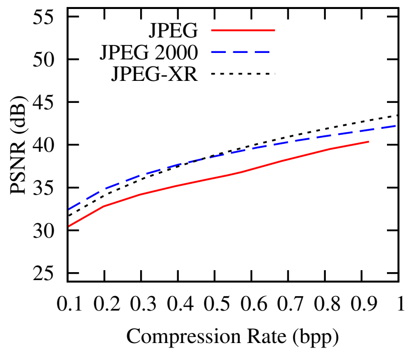
where $MAX = 255$ is the maximum pixel value and MSE is the mean squared error. Note that PSNR is commonly used as an indicator of image quality in presence of signal noise. Generally, the higher the PSNR, the better the quality [5].

A. Visible-range Passport Compression

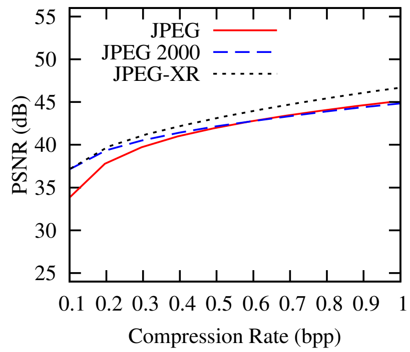
Considering the special class of passport images, we observed the following overall compression behaviour examining 28530 compressed versions of security document images, see Figure 3a and Table II: PSNRs in excess of 40 dB averaged over all images in the considered dataset and comparing images with their uncompressed counterpart can be achieved starting as low as 0.6 bpp for JPEG-XR, at 0.7 bpp for JPEG 2000, and 1.0 bpp for JPEG. As expected over the entire set of readers, JPEG performed worse than the more recent compression algorithms JPEG 2000 and JPEG-XR which performed at similar level. However, using JPEG-XR we obtained slightly better results (especially for higher bitrates) albeit the fact that the algorithm is generally perceived as being slightly inferior to JPEG 2000 in terms of PSNR performance. This is similar to observed effects in iris biometrics [3]. A confidence interval check confirms that the difference between JPEG-XR and JPEG 2000 is significant for the lower and upper ends of tested compression rates, whereas both algorithms are significantly superior to JPEG over the entire range. Table II lists the 95% confidence interval range $\mu \pm e$ (assuming Gaussian model).

TABLE I: Tested document readers.

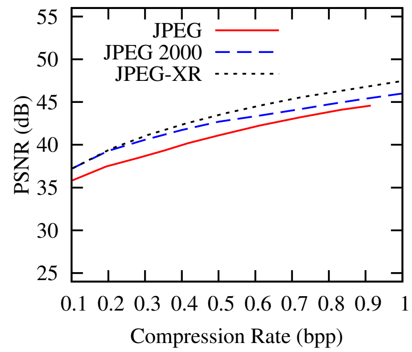
	3M AT9000 MK2	**ARH** Combo Smart	**ARH** PRMc	**Bundesdruckerei** VE 600	**DESKO** ICON Gen I	**DESKO** PENTA Gen 4.0	**Regula** 7024m.111	**Regula** 7034.111	**Suprema** RealPass-V
Resolution (DPI)	400	500	500	400	500	500	380	400	420
Width (mm)	125	125	130	128	131	131	128	128	130
Height (mm)	88	88	98	96	94	94	88	88	90



(a) VIS



(b) NIR



(c) UV

Fig. 3: Compression behaviour of passport data pages per spectrum (VIS, NIR, UV) comparing JPEG, JPEG 2000 & JPEG-XR.

TABLE II: Passport compression's average PSNR with 95% confidence interval per target bitrate, spectrum, and algorithm.

		0.1 bpp	**0.2 bpp**	**0.3 bpp**	**0.4 bpp**	**0.5 bpp**	**0.6 bpp**	**0.7 bpp**	**0.8 bpp**	**0.9 bpp**	**1.0 bpp**
VIS	JPEG	30.34 ±0.28	32.79 ±0.3	34.16 ±0.31	35.17 ±0.32	35.97 ±0.32	36.44 ±0.32	36.81 ±0.35	38.11 ±0.44	39.51 ±0.47	40.38 ±0.44
	JPEG 2000	32.39 ±0.29	34.82 ±0.31	36.39 ±0.31	37.67 ±0.32	38.66 ±0.32	39.68 ±0.32	40.51 ±0.32	41 ±0.32	41.56 ±0.32	42.25 ±0.33
	JPEG-XR	31.7 ±0.3	34.21 ±0.32	36.09 ±0.33	37.6 ±0.34	38.92 ±0.35	40.08 ±0.36	41.09 ±0.37	42 ±0.37	42.86 ±0.37	43.65 ±0.38
NIR	JPEG	33.67 ±0.25	37.79 ±0.32	39.72 ±0.36	40.98 ±0.38	41.94 ±0.4	42.72 ±0.41	43.4 ±0.42	43.97 ±0.43	44.52 ±0.43	44.99 ±0.44
	JPEG 2000	37.12 ±0.31	39.35 ±0.34	40.5 ±0.36	41.43 ±0.37	42.16 ±0.37	42.88 ±0.37	43.5 ±0.38	43.9 ±0.39	44.35 ±0.38	44.84 ±0.37
	JPEG-XR	35.76 ±0.33	37.48 ±0.39	38.47 ±0.42	39.31 ±0.44	40.21 ±0.45	41.09 ±0.45	42.26 ±0.46	43.24 ±0.46	44.09 ±0.46	44.58 ±0.46
UV	JPEG	35.76 ±0.44	37.48 ±0.48	38.47 ±0.5	39.31 ±0.55	40.21 ±0.6	41.09 ±0.62	42.26 ±0.61	43.24 ±0.57	44.09 ±0.53	44.58 ±0.53
	JPEG 2000	37.19 ±0.44	39.29 ±0.48	40.42 ±0.53	41.6 ±0.54	42.56 ±0.58	43.04 ±0.65	43.65 ±0.7	44.16 ±0.71	44.76 ±0.73	45.29 ±0.79
	JPEG-XR	37.26 ±0.49	39.53 ±0.54	41.15 ±0.56	42.5 ±0.57	43.67 ±0.58	44.68 ±0.58	45.58 ±0.58	46.15 ±0.62	46.9 ±0.62	47.64 ±0.63

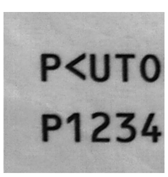
(a) Original

(b) JPEG

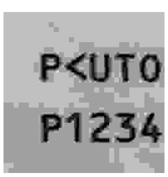
(c) JPEG 2000

(d) JPEG-XR

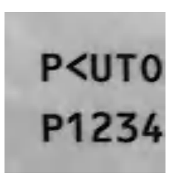
Fig. 4: Compression examples (0.1 bpp) of detail patch in VIS.



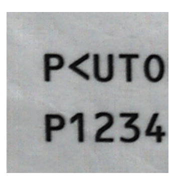
(a) Original



(b) JPEG



(c) JPEG 2000



(d) JPEG-XR

Fig. 5: Compression examples (0.1 bpp) of detail patch in NIR.

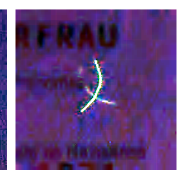
B. Multispectral Passport Compression

The two additional spectral cases NIR and UV exhibit a similar degradation in terms of PSNR, see Figure 3b-c, however it seems that especially the VIS image with about 5dB lower compression performance suffers from compression artefacts, as there is a lot of high-frequency information present. Figures 4, 5, and 6 illustrate samples of patches compressed using the lowest tested quality setting of 0.1 bpp.

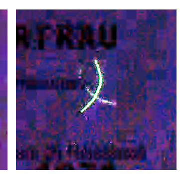
These patches show detailed regions where compression artefacts, due to the low compression rate, are pronounced – all patches are compressed individually, not crop-outs from compressed images. While the advantage of JPEG-XR and JPEG 2000 is clearly visible for the UV and VIS cases, the lack of colour detail is evident for JPEG in case of VIS and background artefacts are clearly visible in both VIS and NIR. Most NIR versions of passports enable good readability of personalized information and dark font in front of homogeneous background is a common texture pattern. With regards to level-of-detail, it seems that JPEG-XR delivers slightly less blurred content compared to JPEG 2000, an advantage which becomes particularly helpful for higher image quality. Given the rich content in the visible range spectrum, it is not surprising to see that PSNR values were generally lowest for this part of the spectrum when compared to NIR and UV for a similar target file size. For the lower end 0.1 bpp setting, the average PSNR for VIS was 31.5 dB, followed by 36 dB for NIR, and 36.7 dB for UV. While at the higher end scale, the average PSNR was 42.1 dB for VIS, 45.6 dB for NIR, and 45.8 dB for UV. We used the average PSNR across all 3 RGB channels for VIS and UV, and single-channel PSNR for NIR.

(a) Original

(b) JPEG

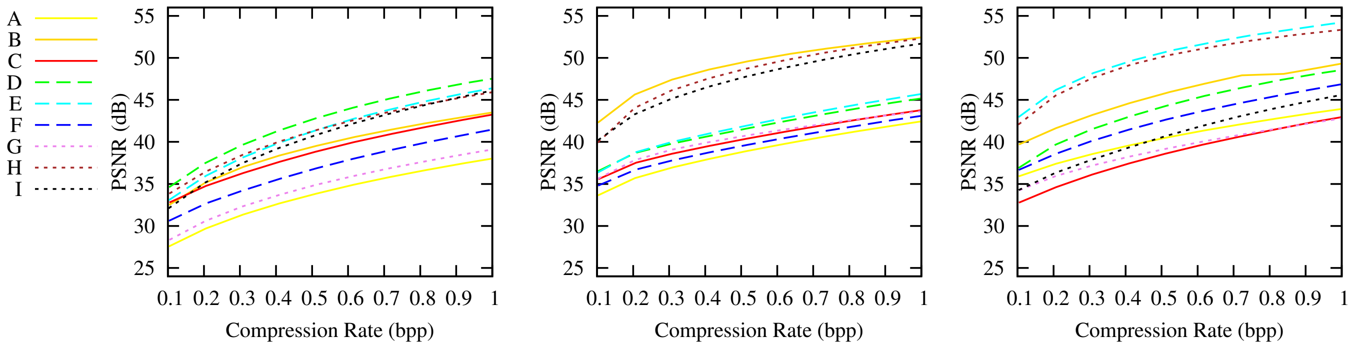


(c) JPEG 2000



(d) JPEG-XR

Fig. 6: Compression examples (0.1 bpp) of detail patch in UV (histogram-stretched after compression to enhance background).



(a) JPEG-XR on VIS (b) JPEG-XR on NIR (c) JPEG-XR on UV

Fig. 7: JPEG-XR compression behaviour of different readers (anonymized, A-I) per spectrum (VIS, NIR, UV).

C. Comparing Readers

As a very interesting side aspect, we looked at the performance across readers for each of the individual spectra, see Fig. 7 and Table III. For VIS performance readers A and G were at the lower end of the scale (i.e., most of the information is affected) and reader D was at the higher end of the scale, reflecting optical resolution behaviour (see [7]). Interestingly, UV and NIR behaviour can not be derived from VIS performance. It is important to note that low PSNR performance is not an indicator of low image quality for a particular reader and even indicates that high-frequency information is lost (which of course can be either noise and/or accurate high-detail information). While readers were considered as black boxes, different image preprocessing is also likely to influence results and access to raw data is usually not possible. For the comparison of readers, noise, distortion, optical resolution and other device characteristics as reported in [7] should be considered.

IV. Conclusion

Comparing compression performance of different lossy image compression algorithms applied to passport images, we found that JPEG-XR clearly outperforms both JPEG and JPEG 2000 across the range of rested devices and (NIR, VIS, UV) spectra. Given its speed is 2-5 times faster than JPEG 2000 [3] depending on bitrate, it provides an interesting alternative to JPEG for storing document images. In order to stay above 35 dB for readers with high optical resolution in visible range, compression rates of at least above 0.6 bpp (JPEG-XR) and 1.0 bpp (JPEG) should be employed. Depending on the underlying compression software, sometimes even with highest quality settings (100) such compression rates could not be achieved in lossy mode. Results comparing different readers should be taken as indicators for the particular reader only, as experiments did not refer to a common ground truth as reference image. Future work may consider including a high-resolution scan of documents as reference image and employ registration techniques for enhanced and reader-independent comparability of PSNR performance.

TABLE III: PSNR comparing compressed with uncompressed data at highest tested quality setting (1.0 bpp) per reader.

VIS at 1 bpp comp. rate target									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
JPEG	44.92	34.86	43.41	42.68	43.84	33.70	38.42	41.37	40.45
JPEG 2000	46.19	38.69	44.62	43.79	45.12	37.52	40.42	42.17	41.95
JPEG-XR	**47.76**	**39.28**	**46.35**	**46.11**	**46.62**	**38.17**	**41.67**	**43.69**	**43.40**
NIR at 1 bpp comp. rate target									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
JPEG	43.46	42.35	49.38	50.47	43.86	40.84	41.44	51.04	42.08
JPEG 2000	**43.59**	42.69	49.23	49.53	43.95	41.10	41.73	49.37	42.41
JPEG-XR	45.43	**43.85**	**52.10**	**52.73**	**45.86**	**42.60**	**43.23**	**52.86**	**43.94**
UV at 1 bpp comp. rate target									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
JPEG	46.07	39.32	43.16	49.50	52.17	41.66	43.42	46.02	40.14
JPEG 2000	47.24	41.67	44.27	51.56	50.41	42.63	45.32	42.67	41.87
JPEG-XR	**48.85**	**42.95**	**45.81**	**53.77**	**54.99**	**44.11**	**47.11**	**48.21**	**43.10**

Acknowledgements

This project has received funding from the EU's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 312583.

References

[1] G. Cui, A. Ivanovic, T. Huang, and L. Chen. Using data compression to enhance the security of identification document. In *Proc. Int'l Conf. Acoustics, Speech and Signal Proc. (ICASSP)*, pages 877 – 880, 2006.

[2] W. Funk, M. Arnold, C. Busch, and A. Mundea. Evaluation of image compression algorithms for fingerprint and face recognition systems. In *Proc. 6th IEEE Inf. Assurance Workshop (IAW)*, pages 72 – 78, 2005.

[3] K. Horvath, H. Stogner, and A. Uhl. Effects of jpeg xr compression settings on iris recognition systems. In P. Real et al., editors, *Comp. Anal. Img. and Patt. (CAIP)*, volume 6855 of *LNCS*, pages 73–80, 2014.

[4] J. Hou, R. Li, Y. Cheng, and H. Shi. Passport photo compression technique with jpeg2000. In *Proc. IEEE Int'l Conf. Mechatronics and Automation (ICMA)*, pages 1389 – 1393, 2013.

[5] Q. Huynh-Thu and M. Ghanbari. Scope of validity of psnr in image/video quality assessment. *Electronics Letters*, 13(44):2, 1998.

[6] L. Rosales-Roldan, M. Cedillo-Hernandez, M. Nakano-Miyatake, and H. Perez-Meana. Watermarking-based tamper detection and recovery algorithms for official documents. In *Proc. 8th Int'l. Conf. Elect. Eng. Comp. Sci. and Aut. Cont. (CCE)*, pages 1 – 6, 2011.

[7] K. Valentin, P. Wild, S. Stolc, F. Daubner, and M. Clabian. Benchmarking of security document readers for automated border control. In *Proc. SPIE Security + Defence*, pages 1–8, Edinburgh, UK, 2016. to appear.

[8] Y. Zhou. Joint robust watermarking and image compression. In *Proc. Int'l Workshop Inf. Forensics and Security (WIFS)*, pages 1 – 6, 2010.