

A Survey on Lossy Compression of DSC Raw Data

(Published 14.5.2007 www.f07.fh-koeln.de/imperia/md/content/personen/fischer_gregor/publikationen/submissioncompressionraw2print.pdf, submitted to the Spectrum Conference at Cologne, Nov. 2007)

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Abstract

The study investigates the lossy compression of DSC raw data based upon the 12 bit baseline JPEG compression. The processing structure of a general compression model is introduced. Two configurations of model parameters are applied to an exemplary high-resolution raw image and compared concerning their performance to compression rate and compression noise.

The results show that this method is capable to achieve compression rates of about 1:5 in practice. The PSNR reaches nearly 70 dB on average of the complete image area and has a similar magnitude as the dynamic range of the used image sensor. Moreover, the sensor noise is being reduced by the JPEG compression procedure without any visual losses of sharpness or details.

Introduction

In digital photography, raw data capturing and processing more and more becomes a common practice. Modern raw converters offer strong tools to optimize image quality after image exposure.

A problem of handling and workflow using raw data is the amount of image data especially for large sensor sizes resulting in long transmission times between internal RAM and external storage media. This applies to the side of the camera during exposure as well as at the side of the PC for post-processing. Additionally, the memory requirements of raw data considerably reduce the maximum number of images that can be stored on memory cards compared to the common JPEG file format.

Up to now, camera manufacturers use lossless or quasi-lossless compression methods by entropy coding and/or nonlinear quantization to reduce the file sizes of raw data. By using these techniques, only low compression rates of about 1:2 are being achieved. Higher compression rates are assumed to be attainable only by lossy compression procedures.

This study investigates the potential and general characteristics of the lossy compression of raw data using the baseline JPEG algorithm.

In still picture technology, the JPEG and JPEG2000 compression techniques have been widely established. The characteristics of both methods have been extensively researched and compared to each other. The results [1-3] show that JPEG has advantages in perceptual image quality for low compression rates

of up to about 1:20. JPEG2000 gains at increasing compression rates.

As low compression rates are of particular interest to raw data compression, our approach focuses on lossy compression using the JPEG method.

Compression Model

We propose the following structure of a compression model to be applied to DSC raw data:

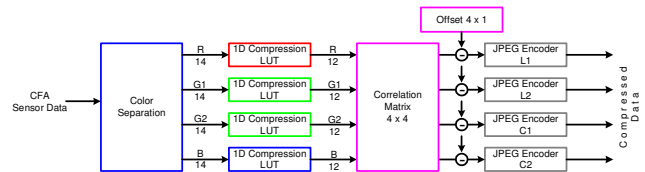


Fig. 1: Proposed compression model

At first the CFA sensor data are separated into the four color planes R, G1, G2 and B. Following, the color signals of a word width of e.g. 14 bit are quantized by a so-called compression LUT to that accuracy necessary for the JPEG encoder, e.g. 12 bit in the example of Fig. 1. The compression LUT might be a linear or nonlinear (e.g. logarithmic) function. After quantization the color signals are mixed by a 4x4 correlation matrix in order to offer a flexible means for utilizing the correlation between the only slightly shifted color planes. The matrix output signals are shifted to the mid of the range of unsigned values by adding a suitable offset. The last step is a separate JPEG encoding of each resulting image plane.

- The 1D compression LUT may follow a logarithmic function similar to Nikon's compression function. If the digital word width should be maintained, the compression LUTs may be omitted.
- The correlation matrix may form a luminance – chrominance transformation emphasizing color differences of the incoming color signals. In order to preserve the digital word width of the output signals, the row sum of its absolute elements should be chosen to unity. As an alternative, the correlation matrix may be neutralized by using an identity matrix.
- The JPEG encoders compress the four color streams independently of each other. They might be controlled by an individual quality factor.

Decompression Model

The data flow to unpack the compressed image streams corresponds to the inverted compression model:

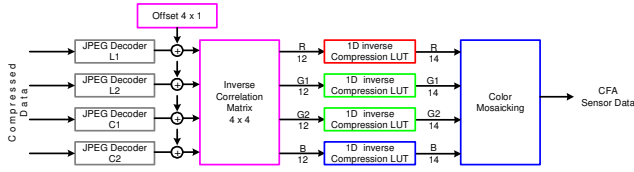


Fig. 2: Decompression engine

The data container within a raw data file format should include all parameters needed for unpacking the compressed raw data:

- Inverse correlation matrix
- Inverse compression LUT
- JPEG control parameters

Experiment

A raw data file of Canon's EOS 5D SLR camera served as input image (see fig. 3). The image consists of a total of 4386 x 2920 pixels and takes a file size of 12.8 Mpixel.



Fig. 3: Image used in this investigation

The image processing is realized in Matlab combined with a modified ddraw raw-converter. The data flow of ddraw is disconnected before the demosaicking step. By that interface, the raw sensor data are transferred to Matlab and processed by the compression and decompression model. Afterwards the decompressed raw sensor data are passed back to ddraw for final demosaicking processing by adaptive homogeneity-directed interpolation. The options of ddraw are set to force 3x16 bit output signals in raw color space.

The following flow chart demonstrates the processing scheme to compare the compressed to the uncompressed processing path by forming a difference image. The difference image is evaluated to provide the PSNR (peak signal-to-noise-ratio) value as a measure of accuracy of the compression model:

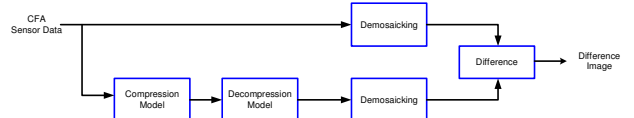


Fig. 4: Evaluation of the PSNR after the demosaicking

We examined the compressability of DSC raw data using the above model with specific settings:

- A linear compression LUT truncates the lower bits of the input signals to limit the LUT's output word width to 12 bit.
- The correlation matrix has been used with two data sets of matrix elements to compare the general behaviour of raw data compression combined with JPEG encoding:

$$M_{Corr1} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, M_{Corr2} = \begin{pmatrix} 0.5 & -0.5 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0.5 & -0.5 & 0 \\ 0 & 0.5 & 0 & -0.5 \end{pmatrix} \quad (1)$$

The identity matrix M_{Corr1} treats all color channels separately and independently both during compression and decompression.

The second matrix M_{Corr2} forms color differences of 2 color signals (except channel G1, 2nd row) and therefore causes interrelations between the compressed signals by the decorrelation matrix during decompression as well. One should expect that color plane differences can be easier compressed than single color planes. The row sum of M_{Corr2} is set to unity to avoid over- or underflows of the output signals.

- For JPEG encoding the Matlab imwrite() function is applied to each image channel L1, L2, C1, C2 separately. The 'Bitdepth' option is set to 12 bit. The quality factor is set identically for all image channels and is used to adjust the overall compression rate.

Using the correlation matrix M_{Corr1} results in the following simple compression model:

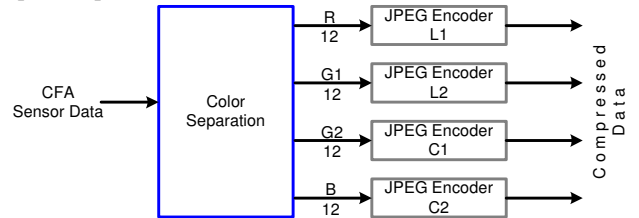


Fig. 5: Compression model 1 using correlation matrix M_{Corr1}

When using the correlation matrix M_{Corr2} the compression model has been modified for optimized compression results using the following processing flow:

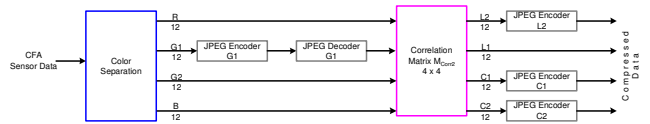


Fig. 6: Optimized compression model 2 using correlation matrix M_{Corr2}

Since the correlation matrix M_{Corr2} mixes every channel with channel G1, this processing structure takes into account the compression deviations of channel G1 before encoding the color differences respective G1 and avoids further error propagation. This optimized compression scheme only affects the compression model, the decompression model has to be left unchanged.

Results

Table 1 presents the numerical results of the compressed file sizes and the PSNR values for different compression models by controlling the JPEG quality factor. Models 1 and 2 are described above. Model 0 means 12bit JPEG compression of the entire sensor raw data without color separation as one single image plane.

Compression Model	JPEG Quality Factor	Compressed File Size KByte	PSNR dB
1. Model 0	70	4409	69,13
2. Model 0	80	5167	72,00
3. Model 0	90	6748	73,85
4. Model 1	80	2801	71,30
5. Model 1	90	4256	73,41
6. Model 2	80	2306	65,82
7. Model 2	90	3642	68,87

Tab. 1: Numerical results of the raw compression survey

As expected, the model 0 effects the largest compressed file sizes compared to the other models. This behavior is caused by a big amount of signal energy within the high spatial frequency band due to the nested color mosaic. The comparison of the favored models 1 and 2 shows that considering the correlation between the 4 color planes entails smaller compressed file sizes using model 2. Otherwise, model 2 exhibits higher compression noise of about 6dB compared to model 1. We assume that the inverse color mixing by the inverse correlation matrix of the decompression engine induces the superimposing of noise portions of the separately compressed and decompressed image planes.

The resulting PSNR values of up to 73 dB over the entire image demonstrate that the signal deterioration by the proposed raw data compression is comparable to the dynamic range of the used image sensor.

Fig. 7 has a closer look to the compression noise structure of the different compression models. All small images (original and difference images see fig. 4) show the same cropping area of 100 x 100 pixels within the original image. To visualize the compression noise of the difference images, the difference signal has been amplified by factor 10, and an offset of half of the maximum amplitude has been added. The original and difference images are displayed by applying a simple 2.2 gamma correction without any additional colormangement.

The image region of fig. 7 has been chosen with small details and high-contrast edges to check the loss of sharpness by the compression process. The difference images do not exhibit any structure of the original image showing that no loss in details has to be expected.

The difference images 1. – 3. disclose a strong affinity of model 0 to color noise due to its compression process without separating the color planes.

The compression noise of model 1 with a quality factor 80 (see difference image 4. of fig. 7) appears to be comparable to that noise of model 2 with a quality factor 90 (see difference image 7. of fig. 7).

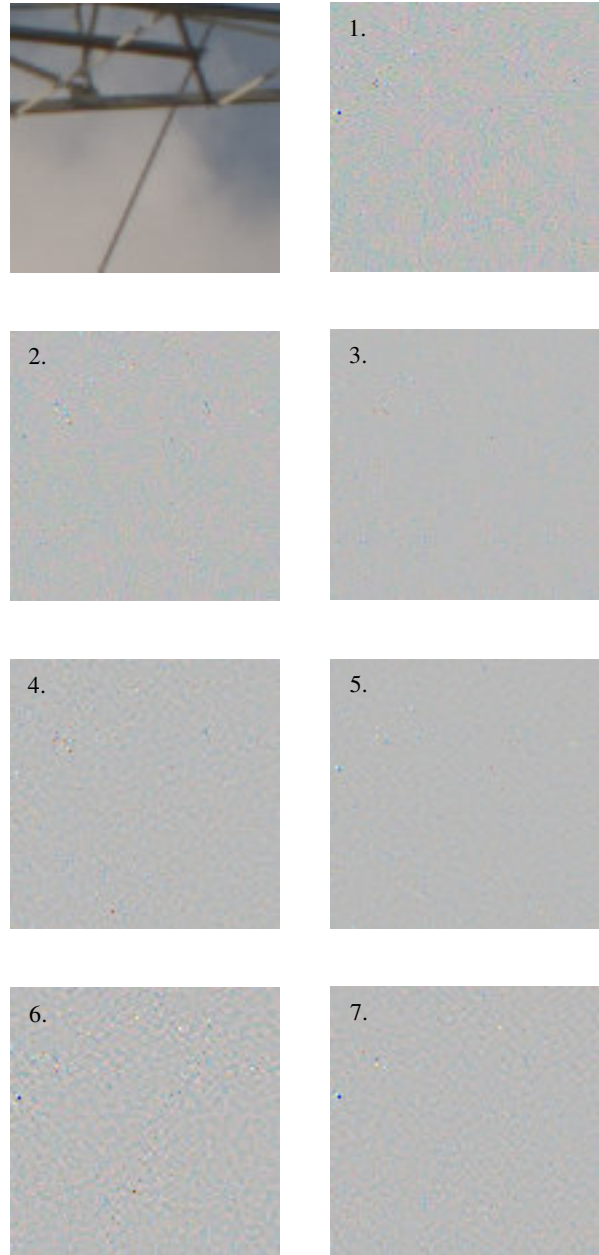


Fig. 7: Original (top left) and corresponding difference images demonstrating the compression noise structure for the various compression configurations of tab. 1.

Another interesting observation can be seen in fig. 8. The compression noise structure of model 1 is opposed for bright (left) and dark (right) image areas. It can be clearly observed that the

noise level in dark areas is much less than in bright areas. We interpret this observation according to the noise characteristic of the image sensor. The JPEG compression performs a low pass filtering of the sensor noise which is increasing with higher signal levels. In consequence, the difference image exhibits higher deviations respectively higher noise in bright image areas. This way, the compression of raw data executes some intelligent kind of noise reduction without loss of sharpness.



Fig. 8: Compression noise structure of model 1 (configurations 4. and 5. of tab. 1) for bright (left column) and dark (right column) areas. The deviations

due to compression appear much less in dark regions compared to bright regions.

Conclusions

The JPEG compression method appears to function as an effective technique to reduce file sizes of DSC raw data. The original file size of 12.8 Mbytes of the exemplary raw image of Canon's EOS 5D could be reduced to a compressed file size of 2.8 Mbytes equal to a compression ratio of about 1:4.5 respectively 1:6.2 compared to the original image data (12.8 Mpix x 12 bit = 19 Mbyte) without loss of perceived image quality.

Moreover, the sensor noise is being reduced by the JPEG compression procedure without any visual loss of sharpness or details. The JPEG compression effects an adaptive multi-band denoising by quantizing the internal DCT base functions.

References

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Author Biography

Gregor Fischer received his diploma in electrical engineering (1990) and PhD in engineering sciences (1997) from the Aachen University. Following he worked in the basic research department for Agfa lab equipment in Munich/Germany. In 2004, Gregor Fischer has been appointed to the phototechnology professorship at the Institute for Media and Imaging Technology of the Cologne University of Applied Sciences. Since 2006 he is a member of the DIN working group for still photography.

His research focuses in image systems design, digital photography and different methods of digital image quality assessment and enhancement.