ANALYSIS OF JPEG2000 QUALITY IN PHOTOGRAMMETRIC APPLICATIONS

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KEY WORDS: Algorithms, Compression, Digital Photogrammetry, Image Processing

ABSTRACT

The recording of a large amount of data required for high resolution digital images is a common problem in digital photogrammetric applications, where several digital images occur for each block. One solution could be, that of using compression algorithms (JPEG, ECW and now JPEG 2000) that allow an extremely large amount of image data to be compressed into a relatively small amount of data. Even the most recent compressor algorithms declare a lossless compression ratio, the most efficient are lossy (the compression of the image data decreases the geometric and radiometric quality information).
The effects of the JPEG2000 compression algorithm on the geometric quality of compressed images is studied in this analisis. This evaluation has been made for the case of automatic and manual stereo plotting. In the first, an automatic Least Square Matching (LSM) collimation procedure was applied to the image of a calibrated grid (acquired with a DTP scanner at 700 dpi) at different compression ratios, and to the uncompressed grid image. The difference between the compressed and uncompressed image coordinates was evaluated. In the second case, a stereoscopic model made up of two aerial photos of the town of Pavia was oriented and used (coupled to several ratio compressed images), to extract the 3D coordinate values of a point set, and to evaluate the differences between the compressed and uncompressed images. The results were compared with those previously obtained by the authors with the JPEG and ECW algorithms.

1. INTRODUCTION

In several digital photogrammetric applications, such as modern Digital Photogrammetric Systems, or 3D navigators (Dequal et al.), one of the main problems is the management of the large quantity of data that is needed for digital image memorization.
The use of compression algorithms is necessary because, while the CPU speeds growth it does not help so much, they allow the space needed for the memorization to be reduced by a few orders. The problem involved regards the effects of these algorithms on the metric quality of the digital images. In order to evaluate the suitability of compression algorithms for photogrammetric application, an evaluation of compression effects has to be made.
Compression techniques can be divided into two groups:
Lossless techniques: these allow image compression without any loss in information: the decompressed images correspond to the original uncompressed images. This is possible thanks to refined rearrangement and redundance removing techniques. The compression ratios are limited to low values, 1/1.5-3.
Lossy techniques (JPEG, ECW, JPEG2000 algorithms), are characterized by elevated compression ratios (up to 1/100), but they introduce a loss in information: the decompressed image do not correspond to the original uncompressed images.
The potential of lossy techniques seems to make them compatible with photogrammetric applications, but the effects have to be considered and evaluated.
These techniques try to minimize the differences between the original images and compressed images, using complex computation algorithms. These algorithms operate in image areas where the human eye cannot appreciate small radiometric changes (variations and noise). Even if limited or adequately chosen, these information losses involve a global decay of the original image, which is revealed in radiometric and geometric distortions. To test the suitability of compression algorithms for photogrammetric applications it is necessary to evaluate the incidence of these distortions on the global image quality.
This kind of study has already been carried out by the authors for JPEG and ECW algorithms (Albery et al, 2001), and is now extended to the JPEG2000 algorithm.

2.THE JPEG2000 ALGORITHM

The JPEG2000 algorithm is based on DWT (*Direct Wavelet Transformation*), which represents an appropriate alternative to DCT (*Direct Cosine Transformation*), which is implemented in the JPEG algorithm.

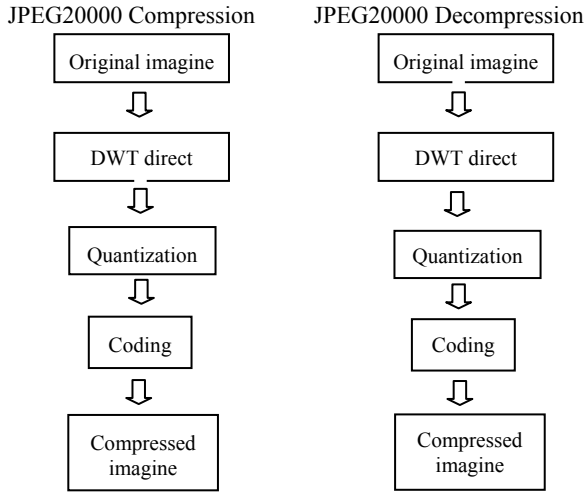

Figure 1 – Baseline process of compression and decompression the JPEG2000 algorithm

The baseline process provides the necessary algorithms for the compression and decompression of JPEG2000 for static images. These algorithms are soon to be implemented in some commercial software package. The procedure is composed of three sequential steps, as described in figure 1:

- DWT (direct or inverse);
- Quantizer (or dequantizer);
- Coding (encoding).

The JPEG2000 standard works on image portions (image tiles). The original image is divided into regular but not overlapped blocks, independently compressed each from other: in this way each block is considered as a single image. Tile is the basic unit of each image (divided and reconstructed).
The tile process (figure 2) reduces the size of the compressed image and allows the decompression algorithm to be applied to

a small portion of the image. All the tiles have the same size, except for the right and low boarders tiles. The tiles dimensions should be arbitrary; this means that an image can be included only in one tile. The effect of the size of the tile on the final quality of the image had been quantified in the past (Christopolous et al. 2002). The effect induced by tiling operations is the reduction of the general quality of an image: the more the image is tiled, the more the artefacts induced by the tiling operation.

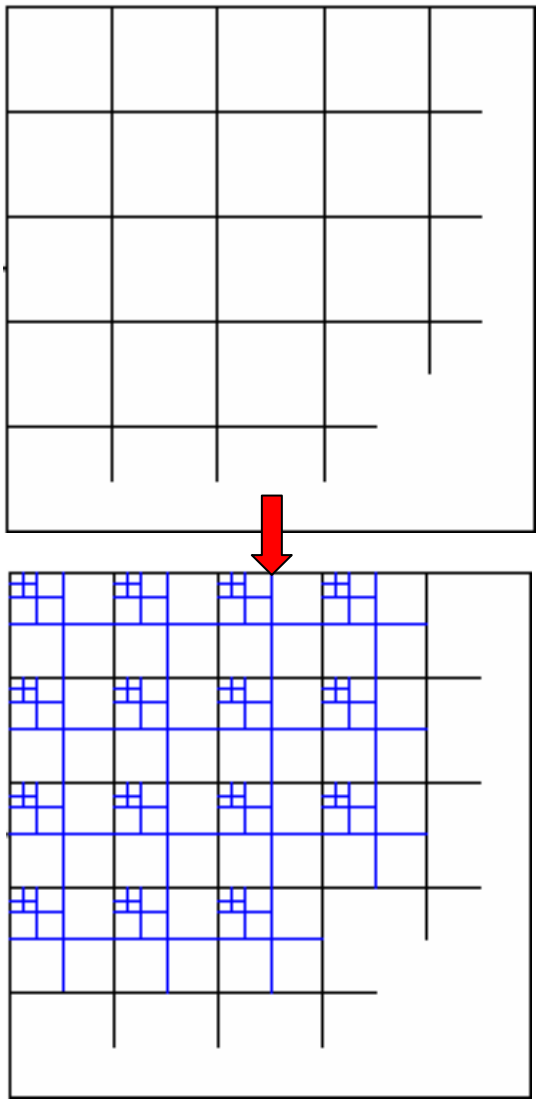

Figure 2 – Tiling on original image

The thus divided image is decomposed into different levels using a DWT transformation. The decomposition level is a coefficient that specifies the horizontal and vertical spatial frequency of each single tile. The DWT splits digital images into two samples: low-pass samples and high-pass samples. Low-pass samples represent a downsampled, low-resolution version of the original set. High-pass samples represent a downsampled, residual version of the original set, which is needed for the perfect reconstruction of the original set from the low-pass set. Repeating the decomposition on low-pass samples, several detailed sub-bands are obtained, whose elements require a few bites to be represented; and an approximate sub-band similar to the original image, but smaller.

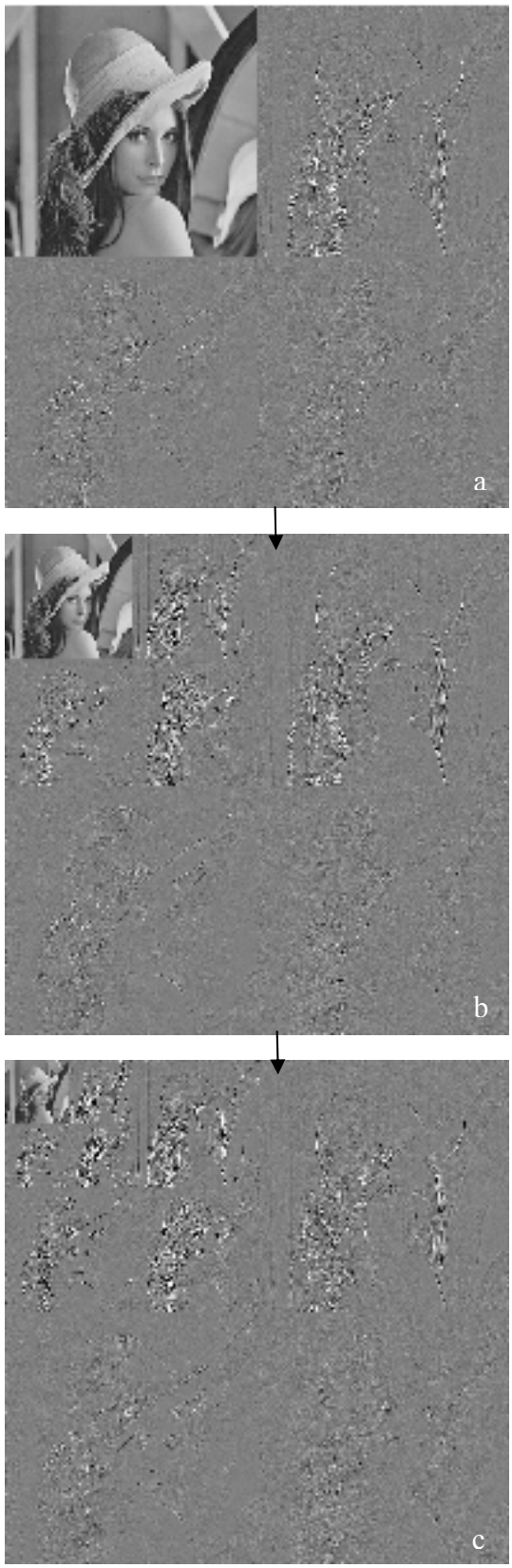

Figure 3 – Decomposition DWT standard

The DWT is a specific transformation for mono-dimensional images, and its suitability for bi-dimensional images requires the choice of a strategy for the conversion of the image in a sample stripe. The most adopted solution is to alternate a row decomposition (arranging one behind another row to obtain the

monodimensional stripe) and a column decomposition(putting the columns in line).
An example of a DWT decomposition in two levels is illustrated in figure 3: the high-left band in the 3b image corresponds to a small copy of the original image, while the other three sub-images contain only the information needed for the original image reconstruction. The two-level decomposition in image 3c clearly shows this step.
Once the DWT transformation has been applied, the main way of reducing the bytes required for image memorization is quantization. Quantisation maps the elements: an element close to zero is coded with a small number of bits. If the number of the elements close to zero is high, an elevated compression ratio can be obtained. The function of the final baseline step, the coding, is to reorganize the memorization by removing the redundant data.

2.1 Compression effects

In qualitative terms, lossy algorithm compression of digital images, results in a global decay that is shown by:

1. fuzziness of the image details (radiometric border);
2. transformation of low-range chromatic areas into uniform chromatic areas;
3. radiometric board shifts (aliasing effect)

Generally, in a compressed image, these effects are not so simple to classify, as compression introduce a distortion mix that gradually increase with the increase of the compression ratio. It is possible to consider that a relation exists between the induced decay and the compression ratio: the increase in the compression ratio increases the distortions, and vice versa, the distortions decrease with a decrease in the compression ratio.
It is necessary to evaluate the entity of the distortion affects in relation to the compression ratio, in order to show the conditions that restrict the use of lossy algorithms in photogrammetric applications.

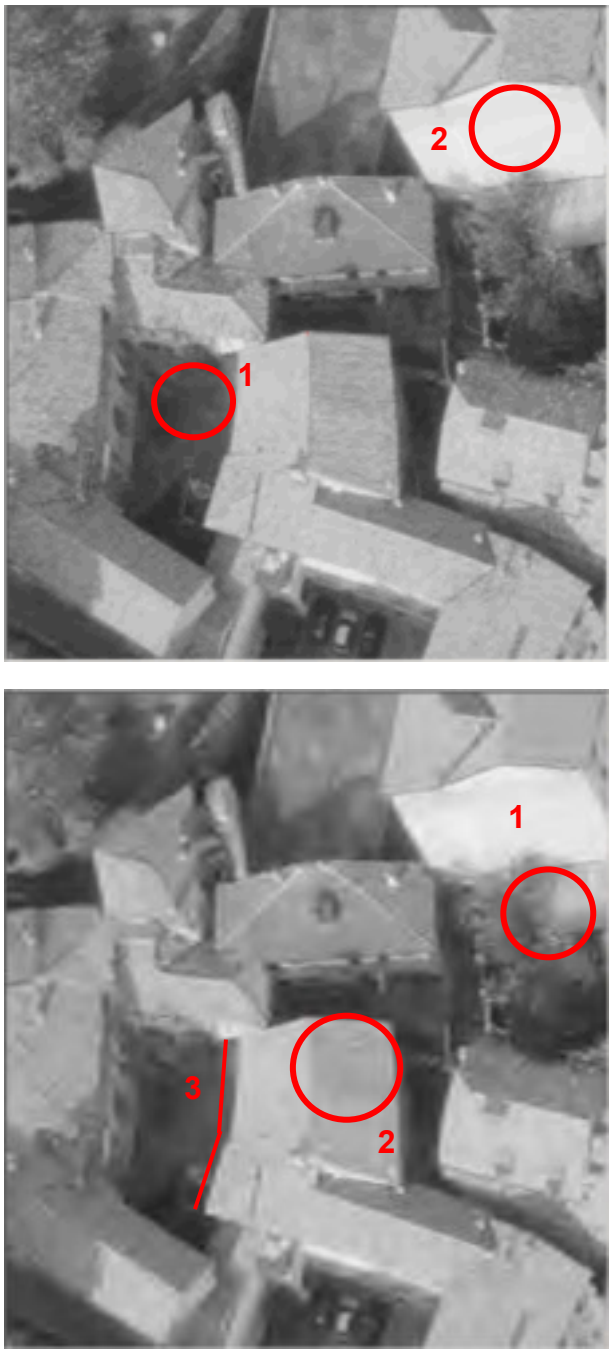

Figure 4 – Particulars extracted at several JPEG 2000 compression levels (original, 1/30, 1/100)

3. ANALYSIS ON DECAY INDUCED BY JPEG2000 COMPRESSION

The decay induced by JPEG2000 compression involves, some difficulties in digital photogrammetry during collimation operations. These effects are also extended to other photogrammetric operations, such as orientation and plotting. Some tests are required to analyze the effective compatibility between the JPEG2000 compression standard and photogrammetric applications. The general purpose is to evaluate the deformations of digital images compressed at different compression ratios, compared with original non-compressed images. The two tests in particular involved two

collimation techniques used in digital photogrammetry: automatic collimation using LSM (Least Square Matching), and stereoscopic manual collimation. An Adobe Photoshop plug-in, called LuraWave.jp2, release 1.1.9.12 was used for the JPEG2000 image generation. The plug-in can be downloaded, in demo trial version, from http://www.algovision-luratech.com/.

The first collimation procedure was performed starting from an image generated by a DTP scanner at 700 dpi resolution (pixel dimension 36 μm). The image represents a grid composed of 10x10 crosses. This image is saved in JPEG2000 format at different compression ratios, from ½, up to 1/100. The 100 crosses are then automatically identified on the different images, using a positioning technique based on an approximate whole pixel positioning algorithm refined by a sub-pixel least square correlation. This technique and the connected software was developed by the authors (Dequal et al., 1996). The differences in coordinates between the same cross in the uncompressed and compressed images was then measured. The results for the Y direction (row direction) are shown in table 6 similarly the same measure can be conducted in the X direction (column direction). The value of the rms of the difference ΔY in relation to the JPEG2000 compression ratio is shown in figure 5 The same comparison was made by the authors for JPEG and ECW formats (Albery et al, 2001), and are here summarized for a comparison purposes.

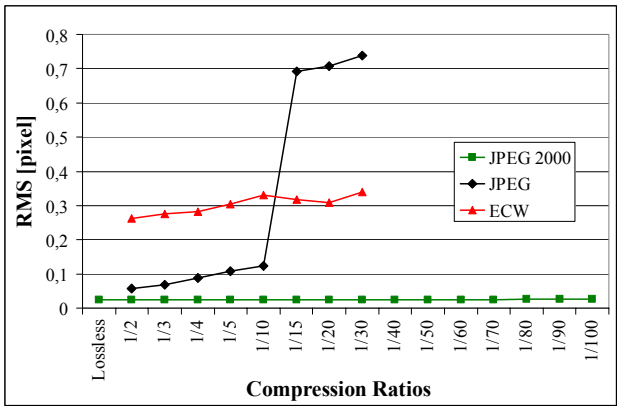

Figure 5 – Graphics of the deformations inducted by JPEG2000 compression

Compr.	Mean	Rms	Min	Max
lossless	0.01	0.02	-0.01	0.09
1/2	0.01	0.02	-0.01	0.09
1/3	0.01	0.02	-0.01	0.09
1/4	0.01	0.02	-0.01	0.09
1/5	0.01	0.02	-0.01	0.09
1/10	0.01	0.02	-0.01	0.09
1/20	0.01	0.02	-0.01	0.09
1/30	0.01	0.02	-0.01	0.09
1/40	0.01	0.02	-0.01	0.09
1/50	0.01	0.02	-0.01	0.10
1/60	0.01	0.02	-0.02	0.09
1/70	0.01	0.02	-0.02	0.10
1/80	0.01	0.02	-0.02	0.10
1/90	0.01	0.02	-0.02	0.11
1/100	0.01	0.02	-0.02	0.11

Tabel 6 - Results LSM (in pixel)

It can be noted (figure 5) how the geometric deformations related to the JPEG2000 compression still remain constant, also for compression ratios up to 1/100, and the absolute value is lower than 1/10 pixel. Therefore, the value of the geometric distortions inducted by the JPEG2000 compression in automatic grid collimation can be considered negligible, and moreover 1 or 2 orders lower than ECW and JPEG distorsions.

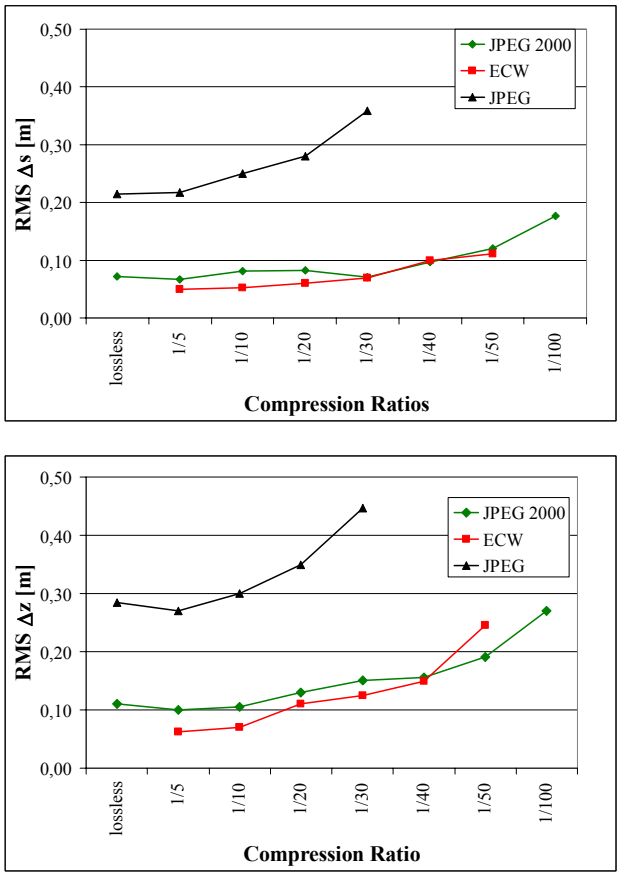

Figure 8 – Graphics of the deformations inducted by JPEG2000 compression

The second manual photogrammetric restitution test was conducted using a stereoscopic model composed of two grey scale images of the town of Pavia (medium scale 1:5000). The images were acquired using a photogrammetric scanner at 1200 dpi (pixel dimension 21 μm). The images were oriented and 50 points were identified in the model. The monographs of these points were compiled. These points were plotted on the model built with uncompressed images, in order to define the reference coordinates. The same images were compressed in JPEG2000 format at different compression ratios. The orientation parameters for the photogrammetric model remained the same, and these parameters were used to compose the models using images at different compression ratios. This condition guarantees that the comparison conditions remain constant. The same set of 50 points was measured in every model, and the differences, in terms of coordinates (Δs as planar coordinates, and Δz for the heights), from the reference coordinates (uncompressed model) were evaluated. The values of the rms of these differences are shown in figure 8 in function of the JPEG2000 compression ratio. The same comparison was also made for the JPEG and ECW formats for the automatically collimation method (Albery et al, 2001), and these are here summarized for comparison purpose.

Figure 9 – Aliasing effects

Finally, it is shown that:

- The Rms trend for the JPEG2000 compression is quite constant up to a 1/40 compression ratio; above this value its trend (especially for the height difference value) tends to increase. In this condition, Rms exceeds the standard precision obtained with the reference model (20 cm). The reasons for this decay can be conducted to the aliasing effects that appeared in the images from the 1/30 compression ratio, especially from radiometric boards and details with directions not parallel to the digital image side (see fig. 9)
- The Rms trend for the ECW compression format is quite similar to the JPEG2000 one, with a noticeable decay over the 1/30 compression ratio;
- The Rms of the difference for the JPEG compression exceeds acceptable values after a 1/10 compression ratio.

4. CONCLUSIONS

The new JPEG2000 compression standard for digital images can be adopted and used in digital photogrammetry applications and it allows a considerable saving in terms of memory needed to save high-resolution images. The only drawback concerns the compression ratio value, which has to be lower than 1/30. Above this, the distortions inducted by a JPEG2000 compression in the digital image introduce some difficulties in collimations procedures (particularly concerning stereoscopic vision). Automatic cross positioning techniques with automatic LSM algorithms are less affected by errors with the JPEG2000 compression, thanks to the limited aliasing effect that is inducted.

REFERENCES

References from Journal

Christopoulos C., Skodras A., Ebrahimi T., (2002) "The JPEG2000 still image coding system: an overview", IEEE Transactions on Consumer Electronics, Vol. 46, No. 4, pp. 1103-1127

Canuto C., Tabacco A., (1996) "Ondine Biortogonali: teoria e applicazioni", Quaderni dell'unione matematica italiana, Pitagora editrice, Bologna.

References Other Literature

Dequal S., Lingua A., Rinaudo F. (1996) "Matching tecniques and algorithms for some Basic Photogrammetric Procedures in the Low Cost Digital Photogrammetric Systems" - International Archives of Photogrammetry and Remote Sensing – Vienna

Rabbani M., Santa Cruz D., (2000) "The JPEG2000 still-image compression standard"

Albery. E., Lingua A., (2001) " Valutazione del degrado Geometrico indotto dalla compressione ECW e JPG nelle immagini digitali", Atti 5° Conferenza Nazionale ASITA – Rimini, pp. 59-64