THE INFLUENCE OF MULTISPECTRAL IMAGE COMPRESSION ON LINEAR AND POINT FEATURE EXTRACTION

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Commission II, WG II/5

KEY WORDS: Photogrammetry, Extraction, Correlation, Compression, Software, Multispectral

ABSTRACT:

The latest experiences in the world show that “lossy” compression could have influence on the geometry and radiometry of compressed images. The geometry of digital image can be tested using the newest method of automatic feature extraction with subpixel accuracy. So high precision of positioning allows for objective comparison of influence of compression on image geometry, using the coordinates of selected features defined in the pixel coordinates system.
In this paper the multispectral images compression is also discussed. The authors have analysed accuracy of reconstruction of linear end point features on the compressed multispectral images. The accuracy of newest method of image compression was tested. The main goal of research was a quantitative definition of the image quality reduction on compressed images, with simultaneous pointing out the optimal compression conditions for measurement and interpretation purposes. The authors studied the question: is it possible to keep the optimal parameters of compression and significantly reduce the size of file, and still have images eligible for high quality measurement and interpretation? In their investigations the authors used the second derivation of digital image as the method providing the subpixel precision of positioning. That method allows localizing the points on digital images with precision of 0,02 pixel. In this paper are presented the measures of quality of digital compressed image accuracy based on localization of linear and point features:

- point measure – RMSE of points position on image after compression referred to image before compression calculated on the base of several points;
- global measure – correlation between images filtered with the Palace’s operator before and after compression.

These measures complement each other i.e. indicate the degree of degradation in the real image selected areas, and on the whole image. The own software named „FES - Feature Extraction Software” allows executing tasks such as localization of features with subpixel precision and calculation statistical data. The calculated RMSE describe geometry degradation very well. In the pixel coordinate system it shows the true value of degradation. The accuracy of linear features is characterized by displacements between their position on the image before and after compression. This measure allows describing well the high frequency changes in the image. The correlation coefficient as global measure indicates very well the degradation on the whole image. It allows showing the change on the feature characterized by low frequency (a big homogeneous areas).

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1. INTRODUCTION

The contemporary world has been developing under the banner of the creating an information society. This means, on the one hand, the need for the intensification of training oriented actions toward a better use of vast information, also geoinformation, on any level of society organization. This precise information helps to undertake smart, proper decisions not only by the administrative and political bodies, but also on the lower levels of society, even in a family. This, however, also means that we need to execute each citizen’s right to an easy access to the databases, and to provide the required information in a form easily understood by everybody. The information presented in a simple format is a set of thematic reports and discussions, graphs rather than tables, photographs, and maps.
In this situation, satellite images and aerial photographs appear to be a very attractive, or even the best carrier of diverse geospatial information. The periodic, fully automated way of collecting aerial and other image information guarantees easy updating. On the other hand, the methods of reading and thematic interpreting of image content is still improving. It becomes possible to extract and decipher more and more hidden information from the images, which is not visible by bare eye before the proper preparation of multispectral images.

The imaging geoinformatics development aims to simplify the reading of images, by properly pre-processing them for easy use by the average man, a man of a diverse degree of knowledge, and also by specialists. This pre-processing of images may result in virtual photomaps, or vector (contour) maps, with special emphasis laid on that thematic information, which is of special interest to the individual user. The expected mass-demand for the good, easy to read pictorial information, calls not only for the fully automated processes of classificying thematic information on images, but also for the greatest possible improvement in the accuracy of reading details. The mass-quantity, and in result, the great volume of raw and pre-processed images, calls for a good method of reducing difficulties connected with storage. Better and better, highly productive methods of digital image compression appear on the market. Unfortunately, the volume-efficient ways of compression cause certain irreversible generalizations of the image content, and, in consequence, a reduction of accuracy, or even readability of small details, which were present on the originals.

In that situation it is very important to prepare software tools, which will enable an objective and easy prediction and judgment of the quality of compression effected images, for various ways of further processing and evaluating the content.

Extraction of any part of an image, which represents a specific terrain use or features, in a final stage of the use often calls for the contouring (vectorization) of the images of those classified fields. Therefore testing the influence of various compression methods on the accuracy of contouring edges of the extracted fields, and inventing still better, more effective and accurate methods of automatic contouring, is at present one of the more important tasks. The users of the imaging geoiformatics have to possess precise tools, which will enable judgment of the risk resulting from the highly effective compression processes (JPEG , or based on wavelets or fractals theory) on the use of various types of images.
Users must also have in their disposal such software tools, which will let them apply effective compressions without the noticeable harm done to the conclusions drawn from the compressed images.

2. THE JPEG AND JPEG2000 COMPRESSION

2.1 Theory

In digital photogrammetry the problem of compression is the key issue from the point of view of the quality of tasks and technological efficiency.
On the base of present experience we can say that the compression ratio in digital photogrammetry, which doesn't have any influence on the results, is a value from 1:3 to 1:10, or even 1:20.
One of the first experiments connected with the estimation of the influence of JPEG compression on the change of positioning of objects on digital images mentioned in (Mikhail, Akey, Mitchell, 1984) were concerned when estimating geometric degradation of compressed images. The authors proved that discrete cosine transform – DCT changes the position of the object (the intersection of lines) in the range of 0.5 pixels with the compression ratio R equalling 1:16 on an 8-bits images. The error increased with the increase of compression ratio.
In the next research on colour images done by (Lammi, Sarjakoski, 1995), who tried to estimate the influence of compression on the quality of images, stated that the degradation could go two ways. The first is radiometrical degradation, the second is geometrical degradation, on which there are movements of linear objects in rows and columns.
Four images were tested: Oryginal, Excellent, High, Fair with compression ratios R equalling 1:7, 1:15, 1:66.
On these pictures, the manual linear object positioning was measured, and next the differences in positioning of given objects were compared. The following conclusion was reached: the method of image compression JPEG doesn't change the geometry of objects when the compression ratio isn't bigger than 1:10.
In 1996 European Organiztion for Experimental Photogrammertric Research (OEEPE), published the results of the aerotriangulation tested done on the block "FORSSA". One of the conclusions was that compression by the JPEG method (up to 1:5) doesn't influence the accurancy of aerotriangulation. This is supported by the results of digital aerotriangulation done by IGIK (Polish Institue of Geodesy and Cartography) on three research projects – images scanned with a resolution of 30 micrometers and compressed with Q=25 on the PhotoScan PS1 ZEISS/INETRGRAPH scanner (Ziobro, Kaczyński, 1998).
The above mentioned paper shows that in spite of long experience in using JPEG compession, there are no definite instructions which could allow for the optimal use of compression for the needs of digital phorogrammetry.
In our paper, we focused on the influence of compression on setting borders between different land usage categories on multispectral images.
JPEG has already a long history. In the eighties JPEG (Joint Photographic Experts Group) worked out the first standard for halftone images. The name JPEG is the synonym for the norm ISO number 10918 from 1991 with the original name Digital Compression and Coding of Continuous-Tone Still Images. It describes the format of data compression, specifies image compression processes and its reconstruction, as well as gives instructions on how to realize these processes. The JPEG standard defines the coder and the decoder by describing the input and output data structure, as well as the methods of transforming one into the other. It also specifies the structure and the proposed auxiliary tables used in the coding and quantization process. Coding a digital image using the JPEG method can be divided into four main steps: colour coding, DCT-transformation, quantization, Huffman coding (Wallace, 1991). The most popular colour coding structure is known as Y C_b C_r, where Y is pixel illumination, C_b C_r is chromination, which can we treated as a pixel saturation of blue and red. Each of these three components is treated as a separate part of the image and is separately transformed and compressed.The final file has interlaced compressed blocks of different components. Colour coding is not used in monochrome images. In this case, the values of the pixels are directly transferred to the DCT (Discrete Cosine Transform).step, which is the essence of compression. It is based on the transformation into frequency space by means of DCT transform. That is still the lossless step of the JPEG method. The only errors that can occur at this step are small errors of rounding up.
Fourier Transform of function f(x) consists of the decomposition of a function for sin and cosin components with different frequencies and amplitudes. It is not a lossy step of JPEG compression, however quantization is. Each of the output values of the DCT transform is 12-bits integer number.
For any JPEG image there is a quantization table of 8 x 8, which is composed of a value, through which data from DCT transform will be divided and later rounded up.
The JPEG decoder has the same table (saved with the image) and it multiplies the values from the files by the adequate position of the table, in order to reconstruct the original DCT data. The bigger the divisor the less exactly we can reconstruct the original values, but the smaller the quantization values, the smaller the JPEG file. The image has a small divisor when the components with the greatest frequency have a divisor of 100 or more. The quantization table (matrix) can be delivered by the user or it can be one of the typical quantization matrixes proposed by JPEG as a result of psychovisual experiments. Besides delivering different quantisation tables , JPEG also allows us to multiply these tables by any number given by the user. This number (multiplier), similar to a quantization table, decides about the quality of the image.

However, the value of the multiplier often doesn't appear directly in the applications. It is replaced by the value Q quality , which is very often restricted by some range. Different systems define the Q compression coefficient differently. It has a deciding influence on the quality of the output image. It is often associated with the compression ratio i.e. the smaller the coefficient Q, the smaller the compresion ratio, and so the file is bigger in size, but it is more similar to the original image. For example, in Intergraph systems the value of the coefficient Q waves between one and one thousand, while in Photoshop systems, Q can take on any value from 1 to 10, where Q = 10 means the best quality, so the opposite as in the Intergraph systems.

In order to improve the funcioning of the standard JPEG algorithm, at the end of the nineties a group called ISO/IEC JTC1/SC29/WG1 started working on a new algorithm, mainly aimed at multimedia technology products. On the second of January 2001 under the number ISO/IEC 15444-1 a new standard was introduced: JPEG 2000. It was supposed to be a standard designed as a coding system for different types of raster data (binary, halftone, coloured, multispectral components) with different spectral characteristics. The main difference between the JPEG standard and JPEG2000 is the type of compression transformation used. In JPEG we have DCT transform, while in JPEG2000 the coding is based on wavelet transformation DWT (Discrete Cosine Transform).

Wavelet transformation, like DCT, comes from the Fourier family, so it has a frequency character, but it also has a time function. This is the advantage it has over frequency solutions,

Thanks to this we don't have to divide the image (as in DCT) into small parts in order to realize the local transformation.

The simplest and historically the earliest frequenly-time signal development was given almost a hundred years ago (Haar, 1910), when it wasn't yet called as wavelet-solution.

The base of wavelet-transformation is the signal approximation of the image using a simple base function (the gate function), which is muliplied in order to model the function with changes based on translation and scaling.

The use of wavelet-transformation to represent images was developed from the end of the eighties (Mallat, 1989).

The image is decomposed into sets of four images with a resolution two times smaller. This task is solved by means of simple lowpass and highpass filters. Lowpass filtering first along rows and than along columns of the image with a double reduction of size creates a medium image - LL (low-low). The next two images are the results of lowpass and highpass filtration LH(low-high). The last component is a result of highpass filtration applied in rows and columns – HH (high-high). Each of these images can be decomposed again, always with a double reduction of size. Use reverse filtration reconstructs the image with no deformations. However, if after decomposition we change the image components, e.g. by cutting small values through the thresholding, then the reconstruction will result in a deformed image. But particular values of images component LL. LH. HL. HH allow us to delete unimportant transformation values, thanks to which the reconstructed image differs very little from the original. This characteristic of wavelet transformation is used to compress images.

The realization of discrete wavelet transformation (DWT - Discrete Wavelet Transform) can be done in different ways (Saha, 1999), the most efficient is thought to be the method proposed by Shapiro of Embedded Zerotree Wavelet coding (Shapiro, 1993).

Similar to the JPEG method, compression takes place during the quantization step, when, while reconstructing the image, we simplify some things, especially at high frequencies (Vetterli, 1995).

Presently there are two technological solutions based on the wavelet method: JPEG2000 (standard ISO) and open standard ECW (Enhanced Compressed Wavelet).

Existing procedures of image compression in JPEG2000: the decomposition of images into four parts conducted in sequence with double reduction of size, which leads to obtaining the next levels of resolution. The filtering of particular subimages through cutting coefficients representing low quantum energy and coding the signal in particular subimages. During this step the image is fully divided into components. The procedures, which change the stream bits unit into the coded data stream are as follows: data from coding blocks are put into layers, the data package from individual layers and individual componenets as blocks are the basic unit of compressed data.

The blocks have a header and can be put in any order, the coded data stream has a header as a beginning describing the original image, the composition of the image, the coding style used, the coder image reconstruction in a given resolution, "region of interest" and other characteristics. The format of the file describes the destination of the image and its components in the application context.

3. THE EMPIRICAL RESEARCH

3.1 Data

In the research the multipsectral images from the Quick Bird satelite were used, with a resolution of 2,4m. These images covered one scene recorded in four spectrums (blue B, green-G, red-R, infrared –IR). Sofware PCI Geomatics (work on 16-bits images, JPEG compression and JPEG2000), Image Analyst (using mathematical analysis) and our own program Feature Extraction Sofware (linear and point extraction) were used..

3.2 Methodology

The original images were divided into four spectrum channels i.e. B-blue, G-green, R-red, N-infrared and saved as different files in TIFF format.

The whole information was saved on 11-bits (a value between 1 and 2047) in 16-bits file, and next the images were compressed into 8-bits file to be reduced by means of linear function to scaling, in order to preserve the shape of the histogram (Fig.1).

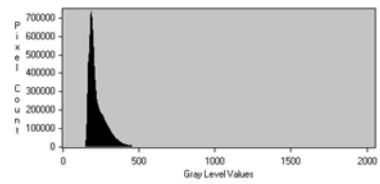

Fig. 1 The histogram of image used in the experiment

These channels (B, G, R, N) were compressed by the JPEG method with a ratio of Q=100, 75 and 50 in PCI Geomatica software, in which Q=100 means the best quality, Q=1 the worst quality (but the smallest file).

For the features extraction (points as the intersection of lines) the second deriviation of the image was used as the method in FES (Mikrut, 2002).
That method allows to determine the points on digital images with a precision of 0,02 pixels.
To determine the influence of compression on the extraction of linear and point features, global and point measures were used to determine the loss of quality.

In this paper we present the measures of quality of digital compressed image accuracy based on the localization of linear and point features:

- point measure – RMSE of point position on an image after compression refers to the image before compression calculated on the base of several points;

- global measure – correlation between images filtered with the Laplace's operator before and after compression.

These measures complement each other i.e. indicate the degree of degradation in the real image selected areas, and on the whole image. Our own software named „FES - Feature Extraction Software" allows for the executing of tasks such as the localization of features with subpixel precision and calculation of statistical data. The calculated RMSE describes the geometry degradation very well. In the pixel coordinate system it shows the true value of the degradation. The accuracy of linear features is characterized by the displacement between their position on the image before and after compression. This measure allows us to describe the high frequency changes in the image well. The correlation coefficient as a global measure indicates the degradation on the whole image precisely. It allows us to show the change on the feature characterized by low frequency (in big homogeneous areas).

4. RESULTS

4.1 Correlation between channels in multispectral images

.Mutual correlation between particular channels were done on the original images (16-bits). In table 1 we present the results.

	B	G	R	N
B	1	0.9788	0.9535	-0.0001
G	0.9788	1	0.9749	0.1015
R	0.9535	0.9749	1	0.0276
N	-0.0001	0.1015	0.0276	1

Table 1. The sets of correlation coefficients for the particular channel

The results of the correlation show a big similarity between visible channels (R,G,B), and we could also see the small correlation in relation to the infrared channel - N.
The best correlation is between B and G (the correlation coeffivient equals 0.9788). N channel has the best correlation with channel G (the correlation coefficient is 0.1015).

From the above sets, we are expecting that the results of compression, linear and point feature extraction in channell N will be similar to the channel G.

4.2 The compression of particular channels

Small parts of images were compressed.
In table 2 file sizes for particular channels and compression ratios for one of the areas are set together (named Test1).
The size before compresion is 3 106 kB.

Q	B [kB]	G [kB]	R [kB]	N [kB]
50	150	228	211	346
75	238	354	328	521
100	1347	1684	1599	2123

Table 2. The set of file sizes after compresion JPEG in [kB] for the particular channels and for selected values of Q – image Test1.

From the above sets, we can see that the best compression is in channel B, which means that in this channel there is less information that in the others, because the compression ratio is better, and at the same time channels G and N have the biggest file size.

4.3 The influence of compression on linear and point feature extraction

In the next step of research, the influence of compression on linear and point feature extraction were studied.
For this purpose two measures were used: global and point (Mikrut, 2002).
The global measure (correlation of two images) was calculated for the original channels (ORY - 16-bits) and reduced to 8-bits (table 3).

Because the data was reduced from 16 to 8-bits, we also examined the coefficients of correlation for these images, to compare it with the results from table 1,

Q	B	G	R	N
ORY - 50	0.9732	0.9807	0.9796	0.9759
ORY - 75	0.9841	0.9889	0.9881	0.9861
ORY - 100	0.9996	0.9999	0.9998	0.9999

Table 3. Table sets of correlation coefficients calculated for the image before compression and after compression for a given Q.

	B	G	R	N
B	1	0.9855	0.9673	-0.0085
G	0.9855	1	0.9822	0.0165
R	0.9673	0.9822	1	0.0774
N	-0.0085	0.0165	0.0774	1

Table 4. Sets of correlation coefficients for particular channels for a part of the image (Test1)

From table 3 and 4 we can see that JPEG compressed images in channel G had the best correlation with the original images (without compression).
The results from the global measure (correlation) are also confirmed by experiments done in the Feature Extraction Software.
The mean errors for this channel are smaller in comparision with the other channels (table 5).
These errors were calculated as the difference in point positioning, extracted on the original image (without compression) in relation to point positioning on the image after compression.
To localize the chosen points with subpixel precision of an algorithm with the second deriviation of digital image implemented in FES was used (Mikrut, 2002).

Q	B [kB]	G [kB]	B[kB]	N [kB]
100	0,543	0,011	0,048	0,041
75	1,801	0,602	1,109	1,066
50	1,703	1,201	1,498	1,097

Table 5. The table set RMS for the point extracted with subpixel precision for particular channels.

The table presents the mean square error for any point calculated as a difference on an image without compression and after compression for a given coefficient Q.

5. CONCLUSION

In this paper the influence of multispectral image compression on linear and point feature extraction were discussed.
The authors have analysed accuracy of reconstruction of linear end point features on the compressed multispectral images.
The geometry of digital image were tested using the newest method of automatic feature extraction with subpixel accuracy. So high precision of positioning allows for objective comparison of influence of compression on image geometry, using the coordinates of selected features defined in the pixel coordinates system.
In this paper authors were presented the measures of quality of digital compressed image accuracy based on the localization of linear and point features:

- point measure – RMSE of point position on an image after compression refers to the image before compression calculated on the base of several points;

- global measure – correlation between images filtered with the Laplace's operator before and after compression.

In the experiments carried out until now, we can clearly see that the best channel for linear and point feature extraction on multispectral images is channel G (green).
This is confirmed by measures used in experiments (global and point measures) and also JPEG compression itself for which compressed files in this channel are characterised by great size of files compared with the other channels, which proves that there is more information in this channel than in others.
A relatively smaller correlation coefficient appeared in the blue channel. The files compressed in this channel are also characterised by the greatest compression coefficient, i.e. they have the strongest compression, so we can assume that this is caused by there being less information than in the other channels.

References:

Haar, A. 1910, *Zur Theorie der orthogonalen Funktionensysteme*. Math. Annal., 1910, vol.69.

Lammi J. i Sarjakoski T. , 1995: *Image Compression by the JPEG Algorithm*, Photogrammetric Engineering & Remote Sensing, Vol. 61, Washington.

Mallat, S., 1989. *Multiresolution approximations and wavelet orthonarmal bases of $L_2(R)$.* Trans. Amer.Math.Soc., 1989, vol.38.

Mikhail E. M. , Akey M. L. , Mitchell O. R. , 1984: *Detection and sub-pixel location of photogrammetric targets in digital images*, Photogrammetria, 39(3), Amsterdam.
Results

Mikrut S., 2002: *Wpływ skanowania i kompresji metodą JPEG na wykrywanie obiektów liniowych i punktowych na obrazach cyfrowych (The influence of scanning and JPEG compression on linear and point feature extraction).* Rozprawa doktorska. Kraków, Poland.

Saha S.,Vemuri R., 1999: *Adaptive Wavelet Coding of Multimedia Images*, Proc. ACM Multimedia Conference.

Shapiro J. M., 1993: *Embedded Image Coding Using Zerotrees of Wavelet Coefficients*, IEEE Trans. SP, vol. 41, no. 12.

Vetterli M., Kovacevic J., 1995: *Wavelets abd Subband Coding. Prentice Hall*, Signal Processing Series, Englewood Cliffs, NJ.

Wallace G. K. , 1991: *The JPEG Still Picture Compression Standard,* Communications of the ACM, 34(4), Washington.

Ziobro J. , Kaczyński R. , 1998: *Analiza wpływu stopnia kompresji obrazu cyfrowego oraz apertury skanowania na późniejszy automatyczny pomiar (Analysis of impact of compression degree of digital image and scanning aperture on automated measurements),* Prace Instytutu Geodezji i Kartografii, Tom XLV, Warszawa.