SŁAWOMIR MIKRUT

WPŁYW KOMPRESJI JPEG NA AUTOMATYCZNE WYKRYWANIE GRANIC UŻYTKÓW Z DOKŁADNOŚCIĄ PODPIKSELOWĄ NA OBRAZACH WIELOSPEKTRLNYCH

THE INFLUENCE OF JPEG COMPRESSION ON THE AUTOMATIC EXTRACTION OF CROPLAND BOUNDARIES WITH SUBPIXEL ACCURACY USING MULTISPECTRAL IMAGES [1]

Abstract

The analysis of influence of the JPEG compression on the automatic extraction of features of cropland boundaries on multispectral digital images was conducted within the framework of KBN research project "The Influence of Compression on the Accuracy of Defining Croplands on the Basis of Multispectral Images". The extraction of such features, as line objects (edges of objects) and points defined as intersection of those boundaries' edges was examined. The evaluation of the image degradation was made visually and analytically. Own software named "FES - Feature Extraction Software," which allows to perform detection of edges with subpixel precision, was applied. Analytical measurements based on statistical data were used to assess the accuracy.

The influence of compression was examined based on chosen loss rates of such qualities, as the RMSE of point position on an image after compression in relation to the image before compression, and correlation between those images. Examinations were performed on QuickBird satellite images, as well as on multispectral aerial photographs.The analysed images were subjected to the JPEG compression. Four spectrum channels were used: blue (B), green (G), red (R) and infrared (IR) in the case of satellite images and green (G), red (R) and two infrared (IR1 and IR2) in the case of aerial photographs. The author has analysed boundaries of croplands and the influence of individual channels and compression on the change thereof. The research showed that during high-ratio compression there appeared an effect of edge segmentation, which was quite considerably visible at the compression ratio of Q = 4. This effect consist in differentiation of distribution of spatial points, depending on the block in which those points are located (8 per 8 pixels).

The approximation of situated edges based on points located in individual blocks leads to the obtaining of sections that do not form straight edge sections but bring them closer stepwise.We can say that when using digital image compression with the compression ratio on the level of 10:1, the RMSE of point position on an image after compression in relation to the original image (i.e. before compression) determined with subpixel accuracy does not exceed the value of 0.5 pixels. The influence of spectral channels on the detection of geometrical features was also examined.

The channels, which gave the best results, were channel 2 (green) and channel 3 (red), at which, the best results were obtained as regards the RMSE and the correlation coefficient, respectively.

[1] Work within the framework of KBN research project No. T 12 E 026 26 "The Influence of Compression on the Accuracy of Defining Croplands on the Basis of Multispectral Images".

1. Introduction

The method of analysis of images described in this paper is part of a wider research conducted within the framework of KBN 4 T12E 026 26 research project "The Influence of Compression on the Accuracy of Defining Croplands on the Basis of Multispectral Images".

During that research, the analysis of the JPEG compression influence on automatic extraction of cropland boundaries on digital multispectral satellite and aerial images was performed. The extraction of such features, as line objects (edges of objects) and points defined as intersection of those boundaries' edges was examined, too. The problem of the loss compression and its influence on images' geometry was discussed from the very beginning of the appearance of the idea to use loss compression in photogrammetry. Its influence on the change of position of objects on digital images was undertaken as early as in the beginning of the 1980s. Mikhail [5] in his research works proves that DCT (Discrete Cosine Transform) changes the position of objects within the range of 0.5 pixels with the use of the 16:1 compression ratio on an 8-bit image. In next research J. Lammi and T. Sarjakoski proved that the "baseline JPEG" image compression method does not influence the images' geometry with the use of the compression ratio not exceeding 10:1 on colour images.

Examinations of the influence of compression on other photogrammetric works can be found in literature. The influence of compression on results of digital aerotriangulation [7][8], and its usefulness for automatic generation of DTM was tested [9]. The influence of compression on extraction of line and point objects with the use of subpixel methods was also presented in works of S. Mikrut [1]. The research results led to conclusions that loss compression could cause the change of geometry and radiometry of compressed images, however, its ratio of 10:1 did not significantly influence the loss of information and accuracy of photogrammetry works.

2. JPEG and current trends of loss compression methods

There are two compression techniques: the non-loss and the loss one. In the loss compression, which also is called an irreversible one, there is an irretrievable loss of information. This causes that an image subjected to compression is not identical to its original. Since photogrammetry deals, mainly, with tonal images, in relation to which the non-loss compression is low effective, it is necessary to use loss compression methods.

The JPEG compression method has been known for years as one of the more effective ones. Its main feature is a good compression coefficient. This is of particular significance in such fields, as photogrammetry, where single images have the size of ca. 1 GB, which – given an average project including, for example, 2000 images – faces the user with the problem of a large disk space. Hence, the JPEG compression has been used for years to reduce the size of files by means of the loss compression. This, however, affects the quality of images used.

The JPEG (Joint Photographic Experts Group) method is the synonym of the ISO Standard No. 10918 of 1991. Detailed description of the algorithm operation can be found in literature [5],[9]. Presently, there are more and more research works implemented, concerning waved and fractal methods of digital image compression. Also the JPEG algorithm has finally been modified and the DCT transform replaced with a waved function and the name of JPEG2000 given to it. However, due to the software availability and effectiveness, it is the classical algorithms that still dominate. There were attempts at comparing the methods [5]. All of them have their advantages and drawbacks. The "Fourier" methods are, for example, good for images of continuous tonality, while the waved methods are more effective for those images, where input signals have sharp impulses.

Still, algorithms based on the JPEG compression have been the ones most commonly used and effective in photogrammetric processes, although the waved algorithms and the fractal ones are just behind them. In addition to the JPEG compression, the JPEG2000 and ECW compressions which are based on the waved functions are becoming more and more popular (the subject is dealt with more broadly in literature [6]).

3. Image Data

Quick Bird satellite images, recorded in four spectral ranges and 1: 8000 aerial images, made by means of the MSK-4 by multispectral camera MSk-4, were used.

3.1 Satellite images

Single, representative multispectral scene from the area of Cracow was used in the research. The spatial resolution of the pixel is 2.4 m (one pixel on the image corresponding to 2.4 m on the ground). The image was recorded on 7th September 2003, and it has four spectral channels. For further examination, the part of the image was chosen, where there were objects to be analysed. The size of the image is 1024 on 1024 pixels. Figure 1 presents the part of the image chosen for examination in four spectral channels. Since the original data are saved at 12 bits, after the histogram analysis, it was decided to reduce the data to 8 bits only, because that range was enough to cover the examined objects (land plot and cropland boundaries).

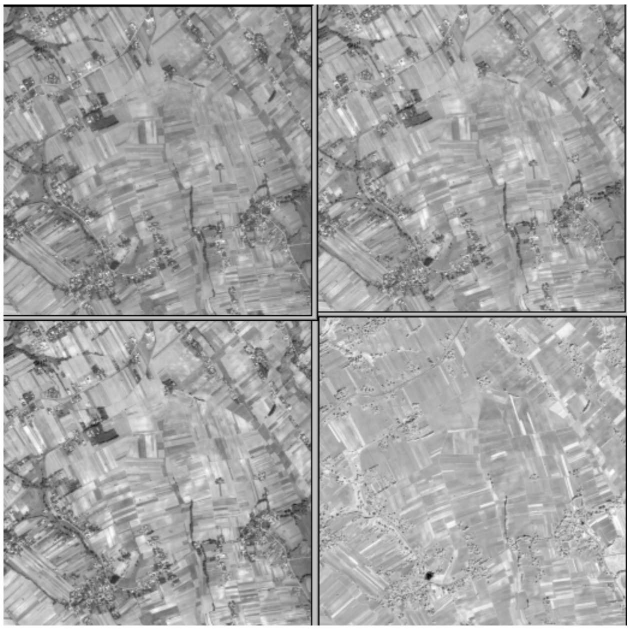


Fig.1 The part of the Quick Bird image and four spectral channels analysed (upper left - the blue channel, upper right - the green channel, lower left – the red channel, lower right – the infrared channel)

3.2 Multispectral aerial images

During research, multispectral aerial 1:8000 images, taken with MSK-4 camera in 2003 were used. Those images were recorded in four channels: green G), red (R), near infrared (NIR1), and the second infrared (NIR2). Parts of croplands, with well-defined edges, were chosen (Figure 2) on those images.

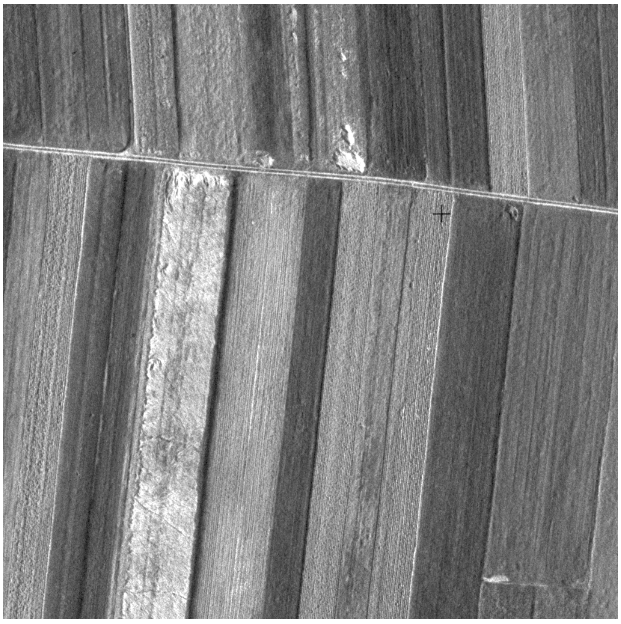


Fig .2. Fragment of an aerial image, recorded in four spectral channels, which was selected for the analyses

4. The research methodology

The evaluation of degradation was done visually and analytically. Own software named "FES - Feature Extraction Software," which allows to perform detection of edges with subpixel precision, was applied. From among many methods of edge detection on digital images, methods based on analyses that enable extraction of edges with subpixel precision were selected, because the aim of research was the determination of the influence of compression on image geometry elements (in particular those elements of the image, which affect procedures of automatic detection of edges on a digital image).

4.1 The software used to research – Feature Extraction Software.

Own software named "FES - Feature Extraction Software," which allows to perform detection of line and point objects with subpixel precision, was applied. This software allows to extract the edges with subpixel methods. It uses the first and the second derivatives of a digital image. Detailed description of the software and its algorithms can be found in literature [5]. In order to use the second derivative method, the original image was filtered by means of the Gauss mask. This step is necessary, because satellite images made from high space ceiling, are characterized by quite a considerable level of noise. This filtering allows to average the image and remove mainly individual "noisy" pixels, which have a big influence on the later subpixel extraction. The original images and those after the JPEG compression, were subjected to low-pass filtering (by means of Adobe Photoshop, the "Gaussian Blur" option), and next followed the extraction of edges by means of FES. The results are presented in paragraph 5.

4.2 The indicators of loss quality

Many authors have been involved in research on the loss quality of images after compression. The experience published in [5],[7],[8] allowed to use those measures, which well determine the properties of an image after compression in relation to the detection of chosen elements on a photogrammetric image (cropland boundaries in our case). The coefficient of the correlation of two images was chosen to be such a measure, as well as the the RMSE of point position on an image after compression in relation to the original image before compression. Those measures, defined in [5], were implemented to the said software.

5. Results

5.1 Satellite images

The original images were compressed by the JPEG method using Adobe Photoshop ver. 6.0. The compression ratios are situated in the range of 0 to 12. The images were compressed with Q compression coefficients of 0, 4, 8, 10, and 12. The sizes of images after compression are shown in Table 1.

Table 1

The set of file sizes of the original image and after the PEG compression for particular Q coefficient values (0, 4, 8, 10, 12) and the image compression ratio calculated as quotient of original file size and the file size after compression (for the first channel)

Image	File size in [KB]	Compression ratio
Oryginal	1025	1
Q=12	562	1,8
Q=10	321	3,2
Q=8	193	5,3
Q=4	111	9,2
Q=0	44	23,3

As we can see in the above Table 1, the image with the maximum compression coefficient of Q = 12 has a great similarity to the original image, but at the same time it is 1.8 times smaller. The maximum compression at Q = 0 gives an image, which is 23.2 times smaller than the original (i.e. without compression) one.

5.1.1. Correlation coefficient

One of the parameters that determine the similarity of digital images is the correlation coefficient. This is a very good measure of the quality loss, which describes the general similarity of an image. In the case of a high coefficient (approximating 1) one says that images show a very great similarity.

In the first stage of research, similarity of spectral channels (all four of them) was checked. The correlation coefficient values of images examined are listed in Table 2. The Table specifies correlation coefficient values of QuickBird images in four selected channels.

Table 2

Specification of correlation coefficient values for images examined in for four spectral channels

Chanel \ Chanel	Chanel 1 (B)	Chanel 2 (G)	Chanel 3 (R)	Chanel 4 (IR)
Chanel 1 (B)	x	0,9758	0,9631	0,0547
Chanel 2 (G)	0,9758	x	0,9711	0,1567
Chanel 3 (R)	0,9631	0,9711	X	- 0,0124
Chanel 4 (IR)	0,0547	0,1567	- 0,0124	x

As the above Table 2 shows, channels 1 and 2 have the highest correlation values. It can also be seen that channel 2 reveals the highest similarity to other channels (0.9758 in relation to channel 1, 0.9631 in relation to channel 3, and 0.1567 in relation to channel 4). The least correlated are channels 3 and 4. Table 3 lists correlation coefficient values, calculated for particular channels and for selected images that were subjected to the JPEG compression.

Table 3

Specification of values of correlation between the examined QuickBird original image and the one compressed in four spectral channels

Compression ratio \ Chanel	Chanel 1 (B)	Chanel 2 (G)	Chanel 3 (R)	Chanel 4 (IR)
Q=12	0,9999	0,9999	0,9999	0,9999
Q=10	0,9998	0,9998	0,9999	0,9997
Q=8	0,9997	0,9997	0,9998	0,9995
Q=6	0,9996	0,9996	0,9997	0,9994
Q=4	0,9991	0,9991	0,9994	0,9986
Q=2	0,9976	0,9977	0,9984	0,9962
Q=0	0,9940	0,9941	0,9959	0,9904

Table 3 shows that correlation coefficient is a good global measure that describes the influence of compression. Images that are compressed at a growing compression ratio reveal higher dissimilarities in relation to their originals.

As the above Table 3 shows, in channel 3 (R) correlation coefficient values are the highest at particular Q values, as compared to other channels. This proves that at a given Q compression coefficient value the quality losses are lower, when compared to neighbouring channels, while the highest losses occur in channel 4 (IR), as has been well shown in Figure 3.

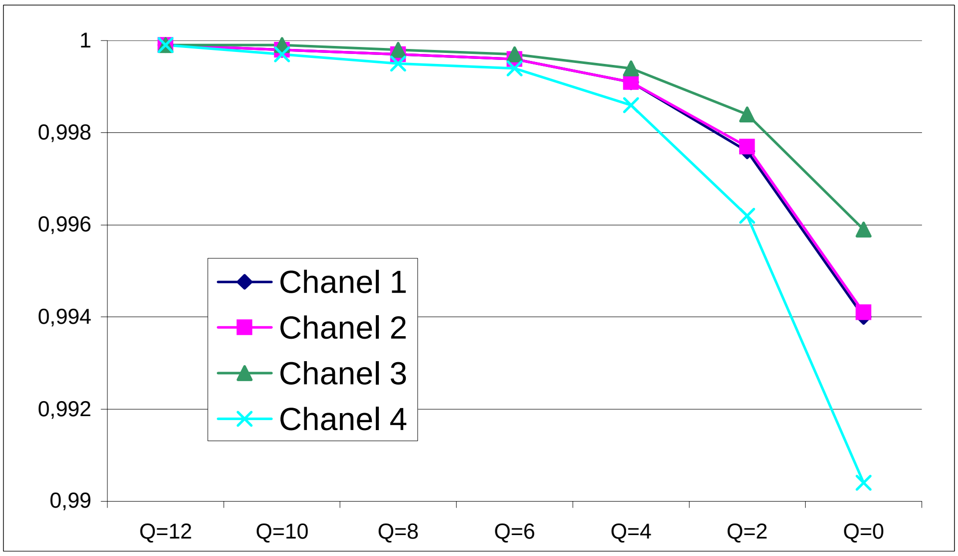


Fig. 3. Dependence between correlation coefficient and compression ratio

5.1.2 Edge detection

The subpixel algorithms allow to locate land plots with the error smaller than the pixel size. In the research, exemplary land plot and cropland boundaries were selected, and position of edges' intersection was calculated for them. Measurements and calculations were made with the use of the "Feature Extraction Software". Table 4 lists the exemplary results.

Table 4

Exemplary results of the RMSE of point position on an image after compression at the Q coefficients of 10, 4 and 0.

Image	RMSE [pixel]
Q=10	0,337
Q=4	0,433
Q=0	0,734

As the above Table 4 shows, the RMSE of point position on an image after compression in relation to the original image (before the compression) increases, following the increase of the compression ratio. To sum up, the higher the compression, the greater the error, and following that, the image geometry changes for the worse.

Fig. 4. Exemplary land plot and cropland boundaries, recorded on a satellite image and utilised in the research

Another criterion of the analysis may also be the number of points detected on a given edge (exemplary land plot and cropland boundaries, which were used in research, are shown in Figure 4). In the case of the first edge, which was 95 pixel long, the number of detected points was 56, 53 and 36, at Q = 10, Q = 4, Q = 0, respectively. The second edge was 17 pixel long, and there were 10, 8 and 8 points detected. It can be seen that the increase of the compression coefficient results in the decrease of the number of points that are detected with the subpixel accuracy.

5.2 Multispectral aerial images

The original images were subjected to the JPEG compression, just like in the case of satellite images, using Adobe Photoshop ver. 6.0. and compression ratios ranging from 0 to 12 (at every two degrees). The images were compressed with the use of the coefficient values of 0, 2, 4, 6, 8, 10, and 12. The sizes of files after compression were listed in Table 5. Figure 5 shows exemplary fragments of multispectral aerial images, together with their histograms.

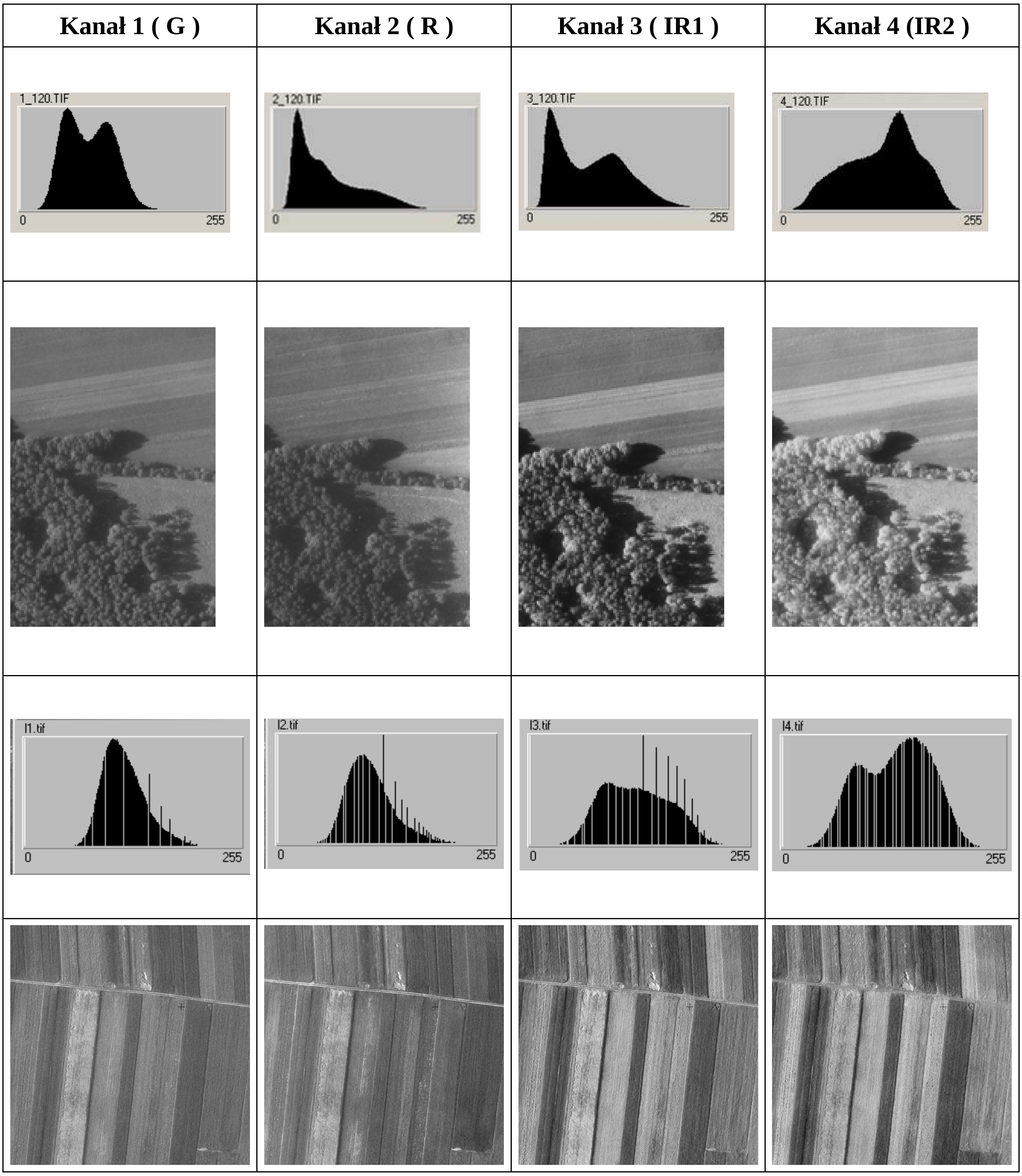
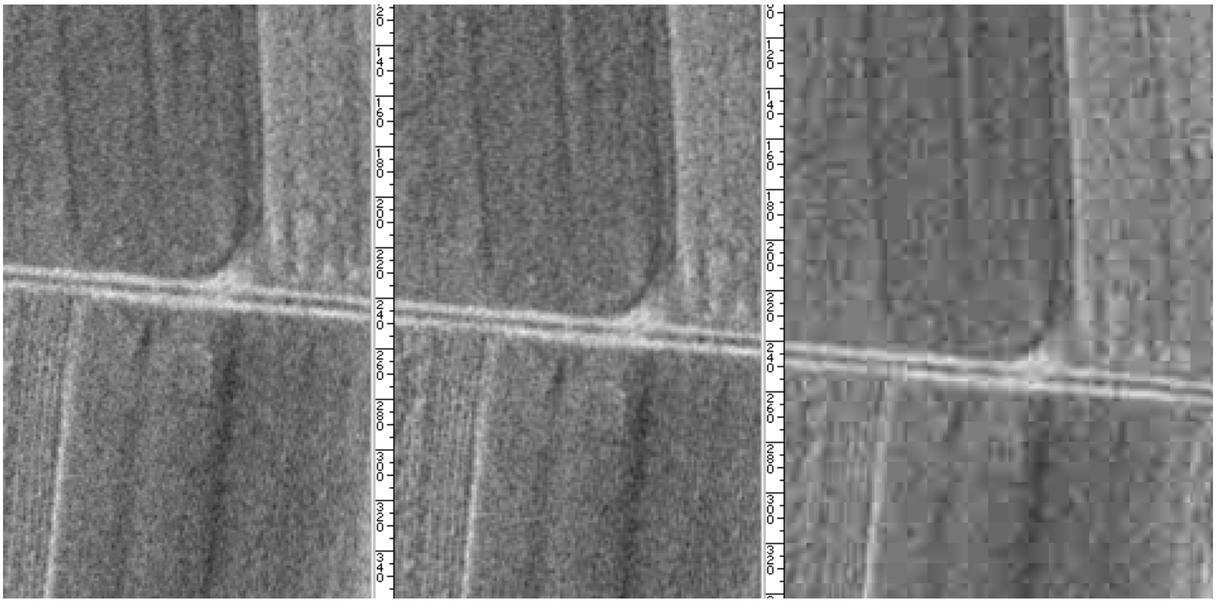


Fig. 5. Two exemplary fragments of an aerial image recorded in four spectral channels with the respective histograms above.



a) b) c)

Fig. 6. A exemplary fragment of an aerial image in channel 1 (G): a) with no compression, b) with Q = 6 compression, c) with Q = 0 compression.

Table 5

The set of file sizes of the original image and after JPEG compression for particular Q coefficient values (0, 2, 4, 6, 8, 10, and 12) and the image compression ratio calculated as the quotient of original file size and file size after compression (for all four channels)

Image	File Size [KB] – Chanel G	Compres ratio	File Size [KB] – Chanel R	Compres ratio	File Size [KB] – Chanel IR1	Compres ratio	File Size [KB] – Chanel IR2	Compres ratio.
Oryginal	1026	1	1026	1	1027	1	1027	1
Q=12	755	1,36	713	1,43	793	1,30	768	1,33
Q=10	468	2,19	431	2,38	509	2,02	483	2,13
Q=8	292	3,51	265	3,87	318	3,23	306	3,36
Q=6	254	4,04	229	4,48	277	3,71	267	3,85
Q=4	165	6,22	147	6,98	182	5,64	178	5,77
Q=2	76	13,5	71	14,45	91	11,29	89	11,54
Q=0	41	25	39	26,31	55	18,67	52	19,75

As the above Table 5 shows, the image with the maximum compression coefficient of Q = 12 has a great similarity to its original, but at the same time it is 1.34 times smaller. The maximum compression at Q = 0 gives an image, which is 25 times smaller than the original one (without compression) – as an example of channel 1. It is worth mentioning that channel 2 (R) compresses best, while channel 3 (IR1) compresses worst.

5.2.1 Correlation coefficient

Analogically to the satellite images, in the first stage of the research, the similarity of particular spectral channels (all four of them) was checked. The correlation coefficient values for the images examined were listed in Table 5. The Table specifies correlation coefficient values of QuickBird images in four selected channels.

Table 6

Specification of correlation coefficient values for images examined in for four spectral channels

Chanel \ Chanel	Chanel 1 (G)	Chanel 2 (R)	Chanel 3 (IR1)	Chanel 4 (IR2)
Chanel 1 (G)	x	0,6890	0,7939	0,6616
Chanel 2 (R)	0,6890	x	0,5412	0,3442
Chanel 3 (IR1)	0,7939	0,5412	X	0,8721
Chanel 4 (IR2)	0,6616	0,3442	0,8721	x

As the above Table 6 shows, channels 3 and 4 show the highest correlation values. It can also be noticed that channel 1 (G) shows the greatest similarity in relation to other channels (0.6890 in relation to channel 2, 0.7939 in relation to channel 3, and 0.6616 in relation to channel 4). The least correlated are channels 2 and 4. Table 7 lists correlation coefficient values, calculated for particular channels and for selected images, compressed with the JPEG method.

Table 7

Specification of coefficients of correlation between the examined QuickBird original image and the one compressed in four spectral channels

Compression ratio \ Chanel	Chanel 1 (B)	Chanel 2 (G)	Chanel 3 (R)	Chanel 4 (IR)
Q=12	0,9998	0,9998	0,9999	0,9999
Q=10	0,9966	0,9975	0,9983	0,9986
Q=8	0,9977	0,9920	0,9934	0,9952
Q=6	0,9842	0,9898	0,9916	0,9938
Q=4	0,9689	0,9802	0,9841	0,9878
Q=2	0,9375	0,9608	0,9693	0,9746
Q=0	0,9116	0,9433	0,9563	0,9627

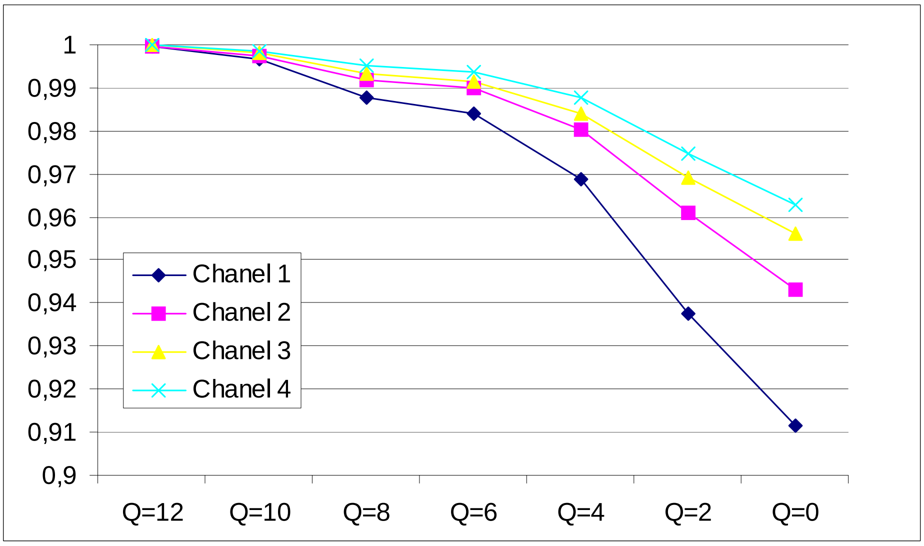


Fig. 7. Chart showing dependence of the correlation coefficient on the compression degree in all four channels

Channel 3 and 4 images are most highly correlated (Table 6). Also the correlation of their counterparts (i.e. images without a compression and images compressed) gives the best results (i.e. the highest correlation coefficients). It can be inferred from that that the highest degradation of an image subjected to compression takes place in channel 1 and channel 4, as compared to the two last ones. Channel 4 compresses the worst, and in channel 4 there is the best similarity of an image after compression in relation to its original.

5.2.2 Edge detection

The RMSE of point position in pixels was calculated for the selected edges. The results related to an exemplary edge are shown in Table 8.

Table 8

Exemplary results of the RMSE of point position on an image after compression at the coefficient values of Q = 10, 4 and 0.

Image	RMSE [pixel]
Q=10	0,27
Q=4	0,47
Q=0	0,81

As the above Table 7 shows, the RMSE of point position on the image after compression in relation to the original (i.e. before the compression) image increases, just like in the case of satellite images, following the increase of the compression rate. It was noticed that at the compression ratio of more than 10:1, the error of the point image position exceeded 0.5pixels (the cropland edge changed its position in that range).

Also visual evaluation of images was performed. It was noticed that images with the compression ratio of not more than Q = 6 were characterised by high similarity to their originals. At higher compression ratios exceeding 10:1, the effects of the JPEG operation became visible (Figure 6).

6. Summary and conclusions

The analyses revealed that the evaluation of the JPEG compression is complicated as regards extraction of line and point objects because of it specific compression features. During the compression the quality of an image is significantly reduced and that worsens the geometric features of the image. By increasing the compression ratio, we get generally higher degradation of a digital image. It is proved by the parameters used in our analyses, that is the correlation coefficient and the RMSE of point position on an image after compression in relation to the image before processing.The analyses revealed also that images compressed with the JPEG compression were subject to process of edge segmentation. The segmentation effect appears at higher compression ratios and it is quite significant at the correlation coefficient lower than Q = 6.

That effect consist in differentiation of distribution of spatial points, depending on the block in which those points are located (8 per 8 pixels). The approximation of situated edges based on points located in individual blocks leads to the obtaining of sections that do not form a straight edge section but bring it closer stepwise.

It can therefore be concluded that when compressing digital images with the compression ratio of 10:1, the RMSE of point position on an image after compression in relation to the original image before compression, determined with the subpixel accuracy, does not exceed the value of 0.5 pixels

Also the influence of spectral channels on the detection of geometry features was examined. The channels that yield the best results proved to be channel 2 (G) and channel 3 (R), for which the best results were obtained as regards the RMSE and the correlation coefficient, respectively. In the case of aerial images, channels 3 and 4 (infrared) gave the best results.

As far, as aerial images are concerned, it is also worth stressing that as together with the wavelength increase, there follows an increase of correlation between images (i.e. between the non-compressed and compressed ones).

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Wpływ kompresji JPEG na automatyczne wykrywanie granic użytków z dokładnością podpikselową na obrazach wielospektrAlnych

The influence of JPEG compression on the automatic extraction OF CROPLAND boundaries with subpixel accuracy using multispectral images

Streszczenie

W ramach projektu badawczego KBN pt. „Wpływ kompresji na dokładność określania użytków na podstawie obrazów wielospektralnych", dokonano analizy wpływu kompresji JPEG na automatyczne wykrywanie granic użytków cech na obrazach cyfrowych wielospektralnych.

Badano wykrywalność takich cech obrazu jak obiekty liniowe (krawędzie obiektów) oraz punkty definiowane jako przecięcie tych krawędzi pochodzące od granic użytków. Oceny degradacji dokonano wizualnie oraz analitycznie. Do badań wykorzystano własne oprogramowanie FES (Feature Extraction Software), pozwalające na detekcję krawędzi z podpikselową dokładnością. Do oceny dokładności zastosowano miary analityczne oparte na statystyce. Wpływ kompresji badano na podstawie wybranych miar straty jakości takich jak: średni błąd położenia punktu na obrazie po kompresji w stosunku do obrazu niekompresowanego oraz korelację między tymi obrazami. Badania zostały przeprowadzone na zobrazowaniach satelitarnych QuickBird oraz wielospektralnych zdjęciach lotniczych zarejestrowanych kamerą MSK-4. Analizowane obrazy poddano kompresji JPEG, ze współczynnikiem kompresji Q w zakresie 0-12 (gdzie Q=0 oznacza obraz o największym stopniu kompresji, tj. maksymalnie zdegradowany, a Q=12, obraz najbliższy oryginałowi). W projekcie wykorzystano zobrazowanie wykonane w czterech zakresach spektralnych: niebieskim (B), zielonym (G), czerwonym (R) i podczerwonym (IR) w przypadku obrazów satelitarnych oraz zielonym (G), czerwonym (R) i dwóch podczerwonych (IR1 oraz IR2) w przypadku zdjęć lotniczych. Postawiono pytanie: jaki wpływ ma kompresja JPEG oraz poszczególne kanały spektralne na zmianę granice użytków rolnych.

W trakcie badań wykazano, że obrazy poddawane działaniu dużym stopniom kompresji, charakteryzuje fakt występowania efektów segmentyzacji krawędzi, co dla współczynnika kompresji Q=4 staje się już dość znacznie widoczne (stopień kompresji bliski 10:1). Efekt ten polega na zróżnicowaniu rozkładów przestrzennych punktów w zależności od tego, w którym znajdują się bloku (8 na 8 pikseli). Aproksymacja przebiegu krawędzi na podstawie punktów zlokalizowanych w poszczególnych blokach prowadzi do uzyskania odcinków nie tworzących krawędzi prostoliniowej a przybliżających ją schodkowo.

Przeprowadzone badania wykazały, że dla obrazów cyfrowych o stopniu kompresji na poziomie 10:1 średni błąd położenia punktu na obrazie po kompresji w stosunku do obrazu pierwotnego (przed kompresją) wyznaczanego z subpikselową dokładnością nie przekracza wartości 0,5 piksela.

Badano również, jaki wpływ ma wybór kanałów spektralnych na detekcje cech geometrycznych. Kanałami dającymi najlepsze rezultaty okazały się: kanał 2 (zielony) oraz kanał 3 (czerwony) dla zobrazowań satelitarnych oraz kanały podczerwone dla zdjęć lotniczych, dla których odpowiednio najlepsze wyniki dawał współczynnik korelacji dla kanału o największej długości fali promieniowania elektromagnetycznego.