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ASSESSMENT OF THE INFLUENCE OF FILTERING SCANNED HISTORICAL AERIAL IMAGES ON THE ACCURACY OF DIGITAL AERIAL TRIANGULATION

ANALIZA WPŁYWU FILTRACJI SKANOWANYCH HISTORYCZNYCH ZDJĘĆ LOTNICZYCH NA DOKŁADNOŚĆ AUTOMATYCZNEJ AEROTRIANGULACJI CYFROWEJ

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KEY WORDS: filtration of images, historical aerial images, aerial triangulation, processing of digital images

SUMMARY: Contrary to aerial images obtained by digital cameras, scanned aerial images are characterized by a lower radiometric resolution and reduced contrast. These parameters have a direct relationship with the quality of the image matching using correlation including the number and accuracy of measurement of tie points in the aerial triangulation. Digital images processing, including filtration in the domain of an object, allows for increasing the contrast, removing noises, and intensifying and detecting edges of objects mapped in the images. This article examines the influence of the key processes of digital image processing on the increase of their measuring and information values. Used in the studies was a block of historical aerial images, covering an area of the western part of Warsaw district, acquired in the 1950s and made available by the Main Centre of Geodetic and Cartographic Documentation (CODGIK). The scope of the study covered the analysis of the impact of selected linear filters, together with high-pass and low-pass filters and also non-linear filters, including statistical and adaptive filters, with different mask sizes, on the accuracy of the field coordinate designation of a tie point in the aerial triangulation. Context operations and also the analysis of contrast correction were carried out in ERDAS 2013. Automatic measurement of tie points together with conducting a relative and absolute adjustment for the block of images orientation were carried out in Inpho 6.0. The results of automatic measurement of tie points for the block of aerial images covered by the radiometric correction were compiled with analogical results obtained for unprocessed images. The measure of the effectiveness of the applied filtration and operations on the images was the mean average error of field coordinate designation of the tie point, the average error of the background coordinate measurement on the image and also the number and distribution of automatically measured ties.

1. INTRODUCTION

Historical aerial images are a valuable source of information in areas like archeology, shaping an environment as well as records of land and buildings. Unlike digital cameras, photographs from analogue cameras are subjected to scanning and have a poorer radiometric quality which measure is among others the radiometric resolution, local image contrast, tonal range and random noise (Pyka, 2007). Numerous studies (Kędzierski, 2004; Pyka, 2007; Jazayeri et al., 2010; Gaiani et al., 2016) indicate a possibility of improving the quality of images, intensification of details, edges detection or elimination of noises in images by using filtration in a space of object or frequency. The choice of the methodology of images radiometric correction should depend on the purpose for which the photographs would be used.

In order to improve the radiometric parameters of historical aerial images, there was examined an influence of image digital processing techniques on the accuracy of automatic digital aerial triangulation, in particular on the accuracy of the automatic measurement of tie points in these images.

2. SCOPE OF THE STUDY

The scope of the study included the analysis of influence of selected filters, linear and non-linear, as well as operations of equalization of the bar chart to the accuracy of automatic digital aerial triangulation of historical aerial images.

Analyses were carried out basing on the alignment of two blocks consisting of respectively 20 and 24 archival aerial images of an approximate scale of 1:10 000, acquired in 1957 for the surrounding area of Kampinos and Błonie (fragments of the western district of Warsaw), characterized by a diversified land use (Figure 1 and 2). Test images were taken in panchromatic, by an analogue camera of 209.86 mm focal length and scanned with geometric resolution of 14μm and radiometric resolution of 8 bits/pixel. Blocks of images had a regular shape. Measured for images Block no. 2 was a set of points of a photogrammetric terrain control network using GNSS technique.

Due to the absence of periodic disturbances in the test images, the studies conducted did not include any filtration in a space of frequency. The filtration using a Fourier transform allows for improving the quality of information in archival aerial images in the case of regular distribution of disturbances occurring in them, but requires an individual approach by designing for each image the filter corresponding to the characteristics of the existing noise (Miałdun, 2012).

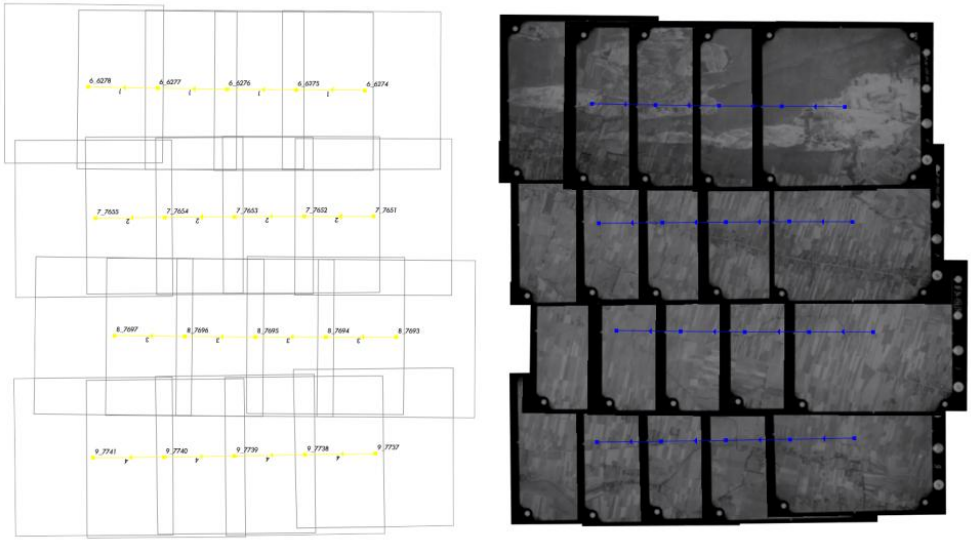

Fig. 1. Block no. 1 of historical aerial images

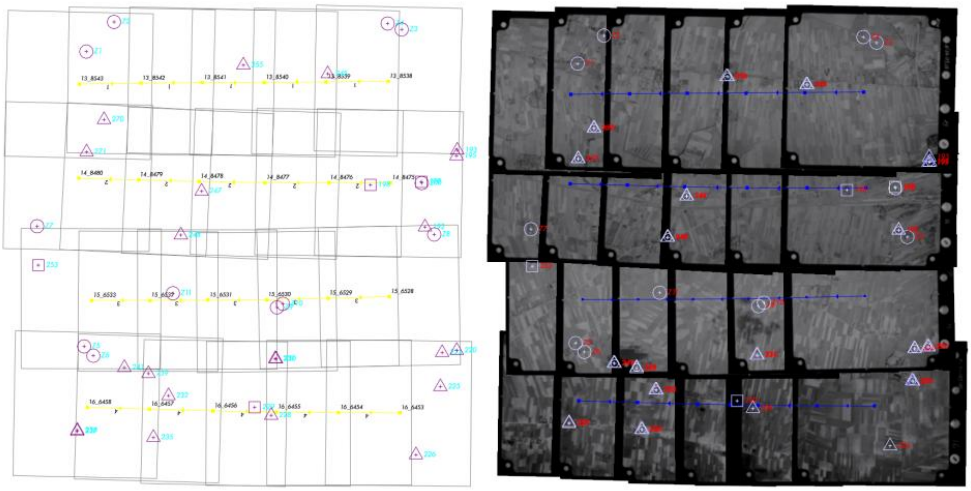

Fig. 2. Block no. 2 of historical aerial images

Transformations used in the studies are presented in the following diagram (Figure 3).

A measure of the effectiveness of the applied filtration and operations on images was an average error of the tie point measurement on the images and a number of automatically measured ties. In the case of Block no. 2, where the GCP's (ground control points) network was measured, the results of equalization of the unprocessed images block along with the results of adjustment of images block subjected to filtration using an adaptive filter were presented.

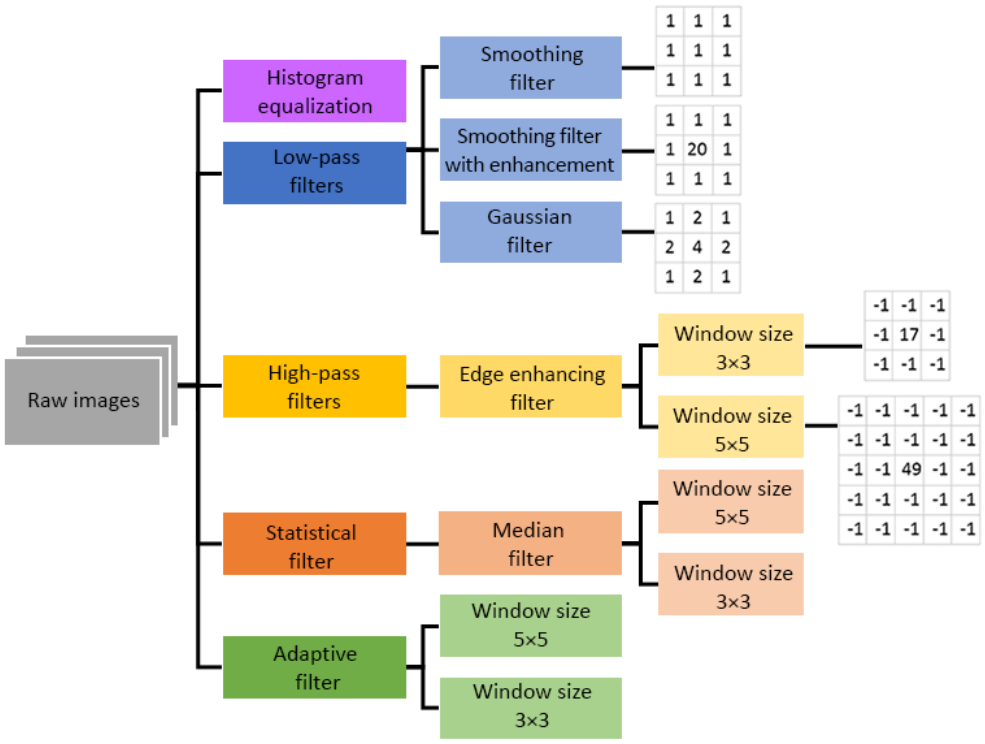

Fig. 3. Diagram of the applied transformations

A histogram equalization based on the transformation of the DN value (digital number) of the image pixels according to a suitably designed LUT table, in order to obtain approximately the same number of pixels with the brightness that would be placed in each of the equal intervals of the histogram, resulted in a significant increase in the contrast of images while simultaneously losing a part of information due to the combination of close DN values of pixels.

The application of low-pass filtration based on the elimination of image elements of high frequency i.e. details (smoothing filter, smoothing with enhancement and Gaussian filter) resulted in the removal of interference and noises in the images. As a result of low-pass filtration by the smoothing filter, blurring of the images texture and deterioration of the detection of contours and shapes of objects could be observed. This effect was minimized by using the smoothing filter with enhancement, where the original pixel value contributes more to the pixel value after processing, and by the Gaussian filter which monotonically damps high frequencies of the image. With this solution, the contours of objects were less “blurred”.

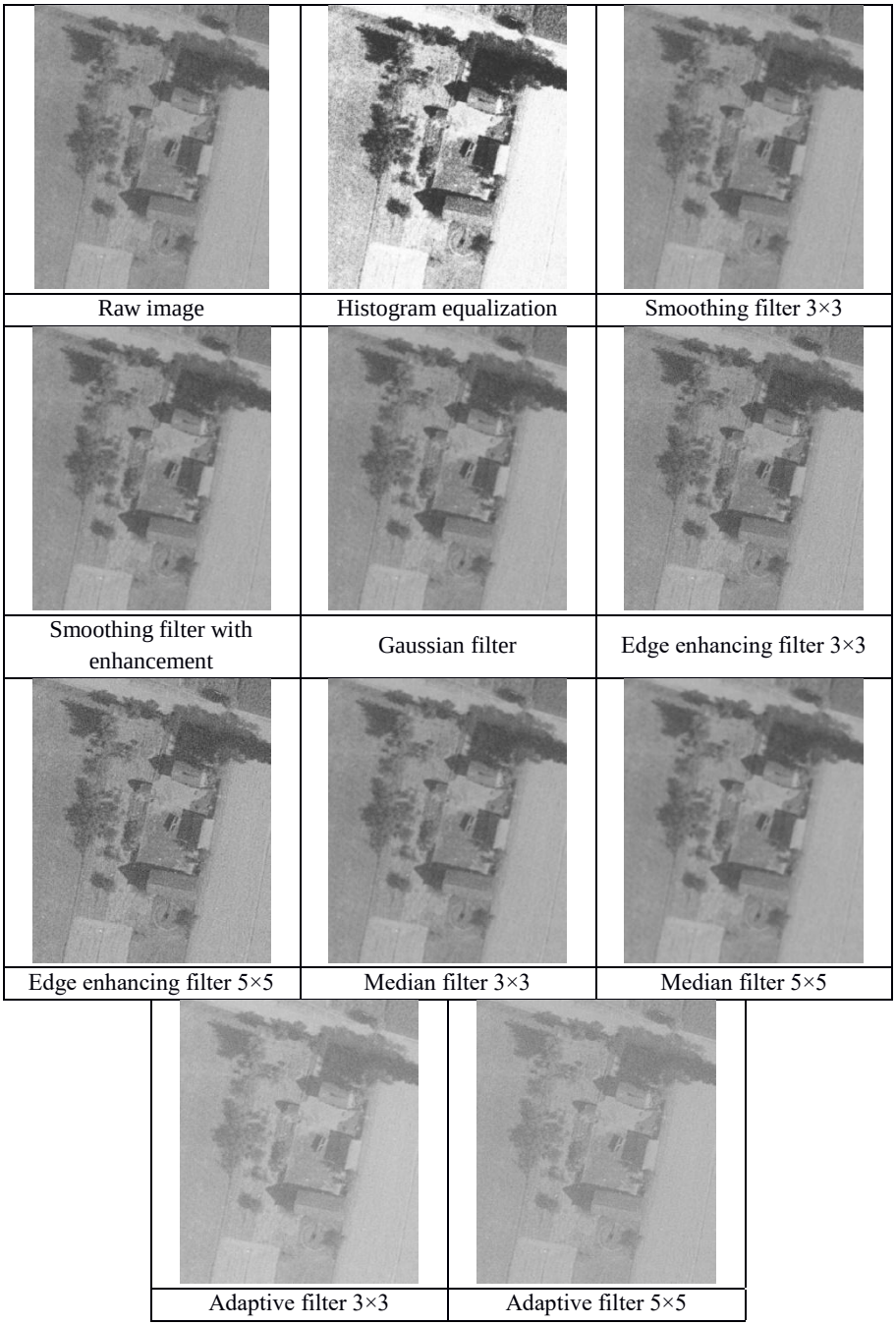

Fig. 4. A fragment of historical aerial image after processing in individual variants

In order to detail contours and boundaries of objects in images, high-pass filtration was applied – an edge enhancing filter with 3×3 and 5×5 mask sizes. The larger size of the mask allowed increasing the immediate environment of the pixel, on which was based the calculation of the DN value on the output image. Due to the poor quality of images, in addition to the edges in images, there was also amplified noise, which, despite an overall sharper image, increased "grain" was visible.

Of the non-linear filters group, based on the local vicinity of the analysed pixel, using local distributions of pixels intensity and their statistical measures, there was applied a median filter and an adaptive filter for 3×3 and 5×5 masks. The operation of the median filter relies on assigning to the central pixel the middle value from the area of the mask, so that this filter satisfactorily removes any local noises, allowing for preserving the sharpness of the existing edges, without introducing any new edges. The principle of operation of the adaptive filter relies on applying the average filter for pixels in the image, classified as not belonging to the edge. For the other areas, the pixel values remain unchanged. As a result of filtration, the contrast on the images was decreased (Figure 4).

3. ANALYSIS OF RESULTS

The automatic measurement of tie points with the relative orientation of Block no. 1 and the absolute orientation of Block no. 2 was carried on in Inpho 6.0. The results of automatic measurement of tie points for the images subjected to the above described transformations were compared with the results of measurements for the original images (unprocessed). Specified in Table 1 were parameters of tie points measurement and parameters of images correlation, whose values were the same for all variants (unprocessed images and after the application of the above specified transformations) for Blocks no. 1 and 2. A combination of methods of images correlation - *Feature Based Matching* (FBM) and *Least Squares Matching* (LSM) was applied.

Table 1. Parameters of the automatic image matching

Parameter	**Value**
Point density	default
TPC pattern	4×4 pixel
Min. distance between points	50 pixel in Level
Size of tie-point area	100 pixel
FBM correlation coefficient	0.92
LSM correlation coefficient	0.93

After completion of the relative orientation of images in Block no. 1, the values for each variant of the filtration were set up, of a mean squared error in the designation of photo coordinates of tie point (Table 2), and also a number of automatically measured tie points (Table 3).

Table 2. Setting-up the average squared errors in the designation of tie point background coordinate in the photographs of Block no. 1

BLOCK 1		σ_0	**RMS**	
		[μm]	**x** [μm]	**y** [μm]
Raw images		5.6	3.8	4.1
a)	Histogram equalization	6.3	4.1	4.5
b)	Smoothing filter 3×3	6.7	4.4	5.0
c)	Smoothing filter with enhancement	6.2	4.2	4.5
d)	Gaussian filter	6.5	4.4	4.8
e)	Edge enhancing filter 3×3	5.6	3.9	4.0
f)	Edge enhancing filter 5×5	5.4	3.6	3.9
g)	Median filter 3×3	6.2	4.1	4.6
h)	Median filter 5×5	7.1	4.6	5.3
i)	Adaptive filter 3×3	5.8	4.1	4.2
j)	Adaptive filter 5×5	6.0	4.2	4.4

From the analysis of the results specified in Table 2 it follows that the lowest value σ_0 was obtained using the edge enhancing filter with the 5×5 mask size (increase of accuracy by 4% in relation to the unprocessed images). The highest error in the designation of photo coordinates of tie point was characteristic for the block of images subjected to the filtration by the median 5×5 filter and smoothing 3×3 filter (decrease of accuracy by 27% and 20% accordingly). This result is due to the highest blurring degree of details in images.

Table 3. A number of tie points observed on 2 or more photographs for block no. 1

BLOCK 1		**Number of points connecting**						
Photos		2	3	4	5	6	Sum	[%]
Raw images		338	236	140	146	15	875	
a)	Histogram equalization	361	184	137	77	4	763	-13
b)	Smoothing filter 3×3	287	202	132	122	10	753	-14
c)	Smoothing filter with enhancement	332	205	152	125	9	823	-6
d)	Gaussian filter	350	209	146	137	9	851	-3
e)	Edge enhancing filter 3×3	322	225	169	136	10	862	-1
f)	Edge enhancing filter 5×5	361	198	141	111	5	816	-7
g)	Median filter 3×3	348	191	137	145	8	829	-5
h)	Median filter 5×5	344	214	152	134	6	850	-3
i)	Adaptive filter 3×3	319	254	148	149	21	891	+2
j)	Adaptive filter 5×5	301	262	158	142	32	895	+2

Considering the number of images, in which the same tie point was automatically measured, the best results were achieved for the block of images subjected to filtration using the 5×5 adaptive filter. In this case, the number of all tie points in the block was increased by 2%, while the number of tie points measured on 6 images after the filtration was increased by 113% in relation to the unprocessed block of images.

The worst results were obtained for the block of images, for which was applied the histogram equalization (due to the individual distribution of pixels intensity for each image), the smoothing 3×3 filter (an excessive blurring of details in the images) and the 5×5 edge enhancing filter (an excessive amplifying the noise in the images).

Measured in 24 images of Block no. 2, were photo coordinates of 32 GCP's (including 18 F-points, 4 P- points and 10 Z- points) and 14 check points. Due to the significant passage of time between taking images and the measurement of the GCP's network, and the essential differences in land cover, GCP's were located on roof ridges of buildings. An example of such location is shown on Figure 5.

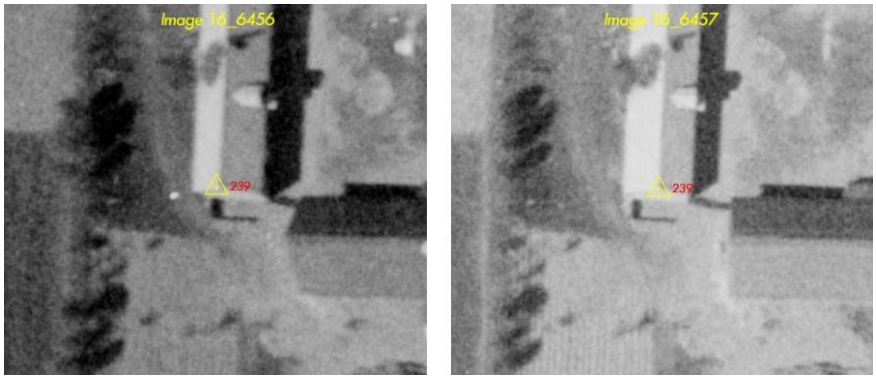

Fig. 5. Example of the location of a GCP on roof ridge of a building

Taking into account the results obtained for Block 1 of the historical aerial images, in the case of Block 2 the analysis of automatically measured number of ties (Table 4) and the analysis of aerial triangulation results was carried out exclusively for the unprocessed images and for the images subjected to filtration by the adaptive filter (Table 5).

Table 4. Number of tie points observed on 2 or more images in the Block 2

BLOCK 2	**Number of points connecting**		Increase/decrease of numer of points conecting [%]
Photos	Raw images	Adaptive filter	
2	474	519	+9
3	316	339	+7
4	149	182	+18
5	34	44	+23
6	74	62	-19
Sum	1047	1146	+9

By analysing the results specified in Table 4, it must be stated that after using the filtration of images with the adaptive filter, there was a nine percent increase in the number of all automatically measured tie points in relation to the block of unprocessed images.

Apart from the number of points observed in 6 images, in all remaining cases there was a significant increase in the number of ties.

Table 5. Statistical evaluation of equalizing the Block 2 of historical aerial images

BLOCK 2		**Raw images**	**Adaptive filter**	**Increase of value [%]**
Sigma naught [μm]	σ_0	5.5	5.4	+2
RMS control points [m]	XY	0.16	0.12	+25
	Z	1.37	1.29	+6
RMS check points [m]	XY	0.19	0.23	-20
	Z	1.96	1.74	+11
Mean standard deviations of terrain points [m]:	XY	0.09	0.07	+22
	Z	0.68	0.61	+10
Mean standard deviations of translations [m]:	m_{X0}	0.59	0.52	+11
	m_{Y0}	1.05	0.80	+23
	m_{Z0}	0.64	0.57	+11
Mean standard deviations of rotations [deg/1000]:	m_ω	28.30	21.70	+23
	m_φ	15.70	14.00	+11
	m_κ	2.50	2.00	+20

The measure of accuracy for the aerial triangulation is primarily the statistical evaluation of the determination of ground coordinates of tie point. The results of analyses indicate an increase of accuracy in setting down the tie point's ground coordinates respectively by 22% for horizontal coordinates XY and by 10% for vertical coordinate Z. The sigma naught $\sigma_{0,}$ after applying filtration was insignificantly decreased (by 2%). On average, in relation to the block of unprocessed images, for the block of images subjected to the filtration by an adaptive filter there was reported 16% increase in the accuracy of delimitation of linear and angular elements of the exterior orientation.

4. SUMMARY AND CONCLUSIONS

Using the historical aerial images for measurement purposes, entails the necessity to precisely determine their exterior orientation elements, which requires applying a GCP's network. Due to the significant passage of time from the taking of images, in many cases, the measurement of such GCP's network within each of them is very difficult, or even impossible. Hence the orientation process of historical images should be referred to the photogrammetric block, whose quality of adjustment is a function of the number and accuracy of measurement of tie points. In the case of historical aerial images, there is a need of their radiometric correction in order to achieve an optimum effect of the automatic measurement of homologous points. Based on the study, it was found that the automatic measurement of tie points on historical aerial images should be preceded by their filtration using an adaptive filter. In the case of a manual measurement of GCP's network, it is advisable to precede the relevant measurement by the filtration for edge enhancing in order to improve indications of terrain details constituting GCP's. The application of filtration by

using an adaptive filter increases the accuracy of the automatic digital aerial triangulation. Depending on the accuracy index, this obtained increase varies from 2 to 25%.

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SŁOWA KLUCZOWE: filtracja obrazów, historyczne zdjęcia lotnicze, aerotriangulacja, cyfrowe przetwarzanie obrazów

Streszczenie

W przeciwieństwie do obrazów lotniczych pozyskiwanych przy udziale kamer cyfrowych, skanowane zdjęcia lotnicze charakteryzują się niższą rozdzielczością radiometryczną oraz obniżonym kontrastem. Parametry te mają bezpośredni związek z jakością pomiaru wykorzystującego dopasowanie obrazów, w tym z liczbą i dokładnością pomiaru punktów wiążących w aerotriangulacji. Cyfrowe przetwarzanie obrazów, w tym filtracja w dziedzinie obiektowej umożliwia zwiększenie kontrastu, usunięcie szumów, a także wzmocnienie i detekcję krawędzi obiektów odwzorowanych na zdjęciach. W niniejszym artykule zbadano wpływ kluczowych procesów cyfrowego przetwarzania obrazów na zwiększenie ich walorów pomiarowych i informacyjnych. W badaniach został wykorzystany blok historycznych zdjęć lotniczych, obejmujący obszar powiatu warszawskiego zachodniego, pozyskanych w latach 50. ubiegłego wieku i udostępnionych przez Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej. Zakres badań obejmował analizę wpływu wybranych filtrów liniowych, w tym górnoprzepustowych i dolnoprzepustowych oraz filtrów nieliniowych, w tym statystycznych i adaptacyjnych, dla różnych rozmiarów maski, na dokładność wyznaczenia współrzędnej terenowej punktu wiążącego w aerotriangulacji. Operacje kontekstowe, a także analiza korekcji kontrastu zostały zrealizowane w środowisku oprogramowania ERDAS w wersji 2013. Automatyczny pomiaru punktów wiążących wraz z przeprowadzeniem orientacji wzajemnej i bezwzględnej bloku zdjęć zostały zrealizowane w środowisku oprogramowania Inpho w wersji 6.0. Wyniki automatycznego pomiaru punktów wiążących dla bloku zdjęć lotniczych objętych korekcją radiometryczną zostały zestawione z analogicznymi wynikami uzyskanymi dla zdjęć nieprzetworzonych. Miarą skuteczności działania zastosowanych filtracji i operacji na zdjęciach był przeciętny błąd średni wyznaczenia współrzędnej terenowej punktu wiążącego, przeciętny błąd pomiaru współrzędnej tłowej na zdjęciu, a także liczba i rozmieszczenie pomierzonych automatycznie wiązań.

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