FILTRATION OF AERIAL IMAGES IN SPECTRAL AND FREQUENCY DOMAIN FOR IMPROVING THE ACCURACY OF AUTOMATIC DIGITAL AEROTRIANGULATION

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ABSTRACT:

Automatic digital aerotriangulation is one of the most essential processes in digital photogrammetry. Nowadays the images used in aerotriangulation are not filtered.
The analysis of accuracy of digital aerotriangulation is based on the following parameters: standard deviations of alignment, RMSE of control points and check points, the quantity of properly generated tie points and the accuracy of exterior orientation parameters.
A dimension of this defects is depended among other things on accuracy with which tie points have been generated. The fact that conjugated pictures created according to rules of perspective projection can differ considerably bringing in geometrical distortions on account of terrain drop, different elements of external angular orientation and lighting conditions and light reflections can distort radiometric pictures on not changed images is very essential.
Therefore digital image matching of such images can have many weaknesses. In result of filtration it is possible to bring out the same terrain details on adjoining images and eliminate the noises i.e. to enhance original pictures without loss of information. The matching coefficient of filtered images will be higher than that of the original ones.
Some procedures of image filtration in spectral and frequency space allow to obtain aerotriangulation results corrected by about 20%. The tests for this contribution have been performed on three blocks (among others block "Echallens") with use of Bingo-F software. Sigma naught has been obtained on the level of 3.9 μm on block alignment. The possibility of using these filtration methods also in automatic generation of DTM it its additional advantage.

1. INTRODUCTION

A majority of present photogrammetic works needs still conducting digital aerial triangulation. Searching, menstruation and transmission of tie points on two or more images using one of image matching methods is the base of automatic digital aerial triangulation. The use of adequate method of filtration of raw scanned aerial images can increase   precision of image matching and accuracy of automatic digital aerial triangulation. Following procedures shown on Fig.1   results of automatic digital aerial triangulation may be improved by about 20%.

2. FILTRATION OF AERIAL IMAGES

Scanning of aerial photographs is done usually with pixel from 15 to 25 μm. Natural points may be used as tie points with condition that image characterize itself adequate texture and contrast. Error of transfer of tie point to next images is one of crucial problems of automatic digital aerial triangulation and mostly depends on method used of image matching and on quality of aerial photographs.

2.1. Filtration in spatial domain

Filtration of scanned aerial images in object space is complex process. Each case of necessity of using right filter may be qualified by following:
- kind of photographed terrain,
- parameters used during aerial photography acquisition,
- atmospheric conditions during exposition,
- errors on film arisen during photo-chemical process,

- errors arisen in process of images scanning,
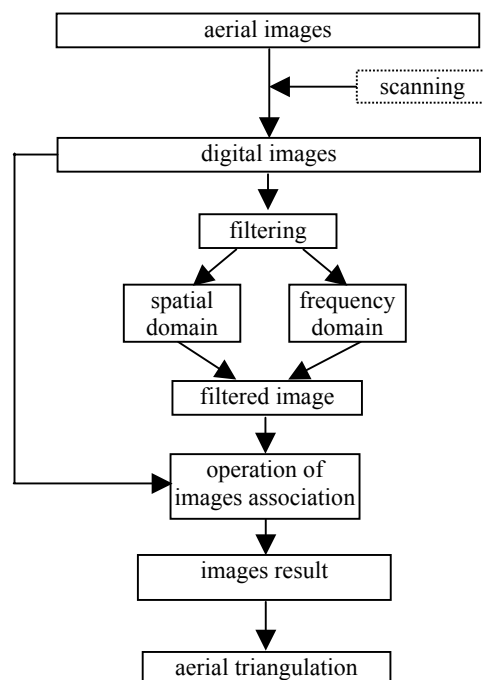- errors in process of further elaboration of digital images.

Fig. 1. Scheme of procedure in aerial triangulation process with filtration of images.

Noise reduction and type of filters used are very important in pre-processing step. Original image could be adequately enhanced by filtering images, but in such way to not disturb information of original aerial image. Method which has been tested is shown on fig. 2.
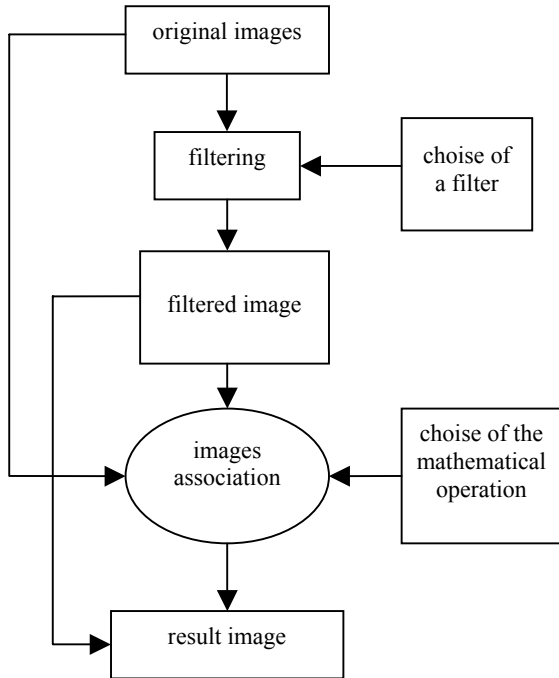

Fig. 2. Scheme of method of image enhancement in spatial domain

Usage of addition operation for two images allows to eliminate weaknesses on original image and to bring out details simultaneously. Addition of images is made by summing of optical density values of adequate pixels of each image, and than conducting normalization.

The other method of filtration used in object space was adaptive filtering. The result of this transformation may be used directly to further digital photogrammetric process.
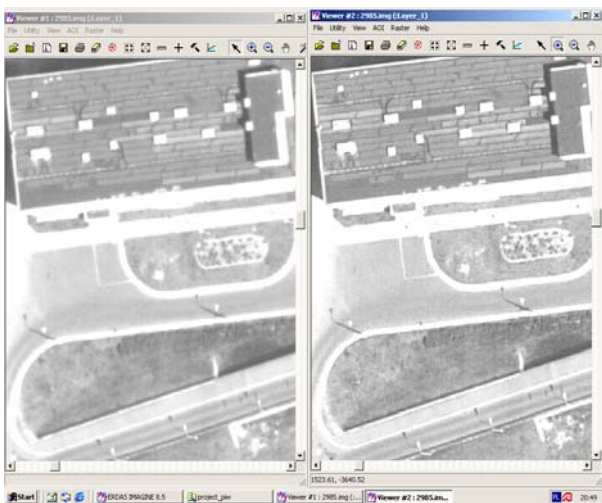

Fig. 3. A part of aerial image, on left - original image, on right - filtered with adaptive filter

2.2. Filtering in frequency domain

Filtering in frequency domain allows eliminate noise and regular errors on digital data.

Aerial images filtering in frequency space do not suit to further using in automatic aerial triangulation process. This possibility exists indirectly as only adequate association filtered image with original one gives an effect that is going to be used in further photogrammetric process. Elaborated and tested method is shown on fig. 4.
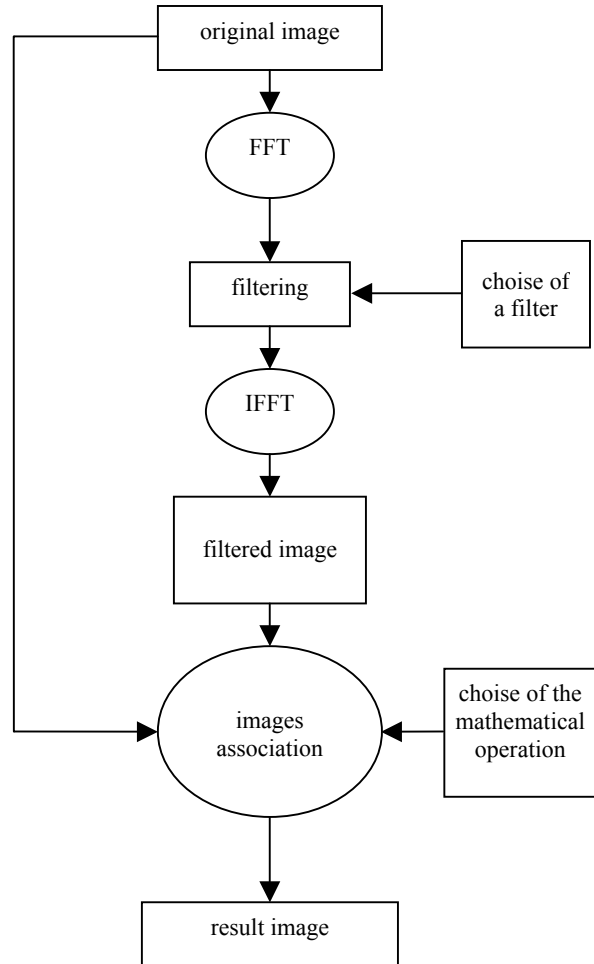
Fig.4. Scheme of the method of image enhancement in frequency space

The example of such association may be a picture arisen in the result of multiplication of an original image with an image filtered with bandpass filter in Fourier space or enhancement (by addition in spatial domain) of an original image with an image filtered by highpass filter in Fourier space. On the figure 6 presenting detail of terrain is shown. We can see sharp enhancement of edges without loosing of any information from the original image.

Fig.5. Association of the original image with the image filtered with highpass filter in Fourier space (by addition of two images)
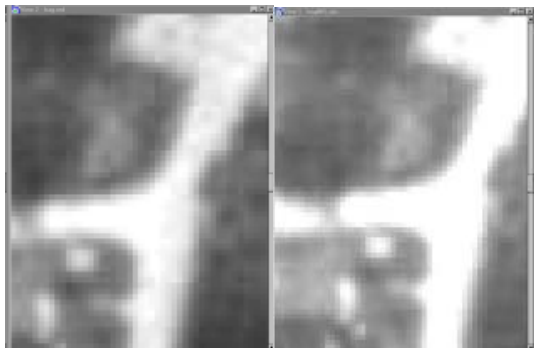

Fig.6. Image on the left - a part of the original image, image on the right - result of enhancement

3. AERIAL TRIANGULATION

Data of three blocks of aerial images with different features and two scales, which are usually used in Poland, is shown in table 1.

Project name	Piwniczna	Bemowo	Echallens
Type of terrain	mountainous	city	flat
Scale	1:28000	1:5000	1:5000
Camera	RC-20	LMK 1000	RC-10
Focal length C_K[mm]	150	300	150
No. of fiducial marks	4	8	4
Film	color	color	b/w
Pixel size [μm]	21	21	21
GCP's	natural	natural	sygnalized
No. of control points	5	6	5
No. of check points	4	5	9
No. of images	3	3	3
RMS (a'priori) GCP's (X,Y,Z) [cm]	50, 50, 30	25, 25, 20	3, 3, 5

Table 1. Characteristic of examined images blocks

To make automatic digital aerotriangulation Orthobase Pro of ERDAS software were used. This software realize this task using ABM method of image correlation - according to Grüns algorithm.

Additional assumptions have been set up:
- mean error of menstruation of fiducial marks on each picture after transformation can not exceed 10 μm,
- location of GCP's should provide regular coverage in the block,
- invariability of GCP's and independent check points (ICP) location after filtration.

Image Analyst Z/I Imaging software was used for filtration and Orthobase Pro ERDAS Imagine.

Following filtration methods have been tested:
- filtration in spatial domain with gradient filters,
- filtration in spatial domain with adaptive filter,
- filtration in frequency domain with highpass filter.

For such kinds of filtration I have choosen following ways of original images enhancement:
with a view to simplify record informing about type of enhancement at the end of above mentioned description I have placed a number characteristic for particular filtration. In combination with the first letter of the images block name (P-Piwniczna, B-Bemowo, E-Echallens) this is univocal information about the block and the enhancement type. The digit 1 was reserved for original images.

In spatial domain:
- original image enhanced by addition a result of filtration of original image using Sobel's mask {9},
- original image enhanced by addition a result of filtration of original image using Prewitt's mask {3},
- original image enhanced by addition a result of filtration of original image using highpass filtrer {10},
- original image filtered with adaptive filter {6},
- original image filtered with adaptive filter with equalization of histogram {7},
- original image with equalization of histogram {5}.

In frequency domain:
- original image enhanced by addition a result of filtration of original image using highpass filtrer with ideal window {8},
- original image enhanced by addition a result of filtration of original image using highpass filtrer with Butterworth's window {2},
- original image filtered with highpass filter with Butterworth's window {4}.

In spatial and frequency domain:
- original image filtered with adaptive filter (in object space) and enhanced by addition a result of filtration of original image using highpass filter with Butterworth's window (in frequency domain) {11}.

The best results of automatic digital aerial triangulation are shown in tables 2, 3, 4.

	P6	P11	P3	P9	P2	P1
σ_0 [μm]	5,1	5,5	5,5	5,6	5,6	5,7
RMS X, Y, Z GCP's [m]	0,11	0,11	0,14	0,13	0,11	0,13
	0,18	0,18	0,17	0,18	0,18	0,17
	0,31	0,32	0,34	0,33	0,33	0,32
RMS X, Y, Z check points [m]	0,81	0,82	0,83	0,83	0,83	0,85
	0,93	0,94	0,95	0,95	0,96	0,97
	0,84	0,86	0,87	0,87	0,87	0,88
No. of tie points	113	112	109	112	110	115
RMS X_0 Y_0 Z_0 [m]	0,30	0,30	0,32	0,32	0,32	0,33
	0,28	0,28	0,30	0,30	0,30	0,30
	0,12	0,13	0,13	0,13	0,14	0,14
ω φ κ ['']	11	11	12	12	12	12
	12	13	13	13	13	14
	4	4	4	5	5	5

Table 2. Results of aerial triangulation in project Piwniczna.

	B6	B11	B3	B2	B9	B1
σ_0 [μm]	6,8	7,3	7,3	7,5	7,5	7,6
RMS X, Y, Z GCP's [m]	0,10	0,11	0,11	0,11	0,11	0,10
	0,03	0,03	0,03	0,03	0,03	0,03
	0,20	0,25	0,24	0,23	0,23	0,22
RMS X, Y, Z check points [m]	0,31	0,32	0,32	0,31	0,31	0,31
	0,27	0,27	0,27	0,27	0,27	0,27
	0,50	0,50	0,48	0,49	0,49	0,48
No. of tie points	116	120	121	123	117	118
RMS X_0 Y_0 Z_0 [m]	0,21	0,21	0,22	0,22	0,22	0,23
	0,38	0,40	0,41	0,41	0,41	0,43
	0,12	0,13	0,13	0,13	0,13	0,14
ω φ κ ['']	51	52	55	56	55	58
	27	27	28	29	29	30
	7	7	7	7	7	8

Table 3. Results of aerial triangulation in project Bemowo

	E6	E11	E2	E9	E3	E1
σ_0 [μm]	4,1	4,4	4,4	4,4	4,6	4,7
RMS X, Y, Z GCP's [m]	0,03	0,03	0,03	0,03	0,03	0,03
	0,05	0,05	0,06	0,06	0,06	0,06
	0,08	0,07	0,09	0,08	0,08	0,09
RMS X, Y, Z check points [m]	0,04	0,04	0,04	0,04	0,04	0,04
	0,05	0,06	0,06	0,06	0,06	0,06
	0,11	0,11	0,12	0,10	0,11	0,11
No. of tie points	141	135	128	135	139	127
RMS X_0 Y_0 Z_0 [m]	0,04	0,04	0,04	0,05	0,05	0,05
	0,05	0,05	0,05	0,05	0,06	0,06
	0,02	0,02	0,02	0,02	0,02	0,02
ω φ κ ['']	10	11	11	11	12	12
	9	10	10	10	10	11
	4	4	4	4	4	4

Table 4. Results of aerial triangulation in project Echallens

Bingo-F for block adjustment of Echallens has been used. I have adjusted original block and the block where original images were enhanced by addition a result of filtration of original image using highpass filter with Butterworth's window and the block where original image was filtered with adaptive filter. As the result the best images after their enhancement in object and frequency space were elaborated.

The results of AT are presented below.

	E6	E2	E1
σ_0 [μm]	3,9	4,2	4,4
RMS X, Y, Z GCP's [m]	0,02	0,02	0,02
	0,02	0,02	0,02
	0,03	0,03	0,04
RMS X, Y, Z tie points [m]	0,03	0,03	0,03
	0,03	0,03	0,04
	0,07	0,07	0,07
max RMS X, Y, Z tie points [m]	0,05	0,06	0,06
	0,05	0,06	0,07
	0,08	0,09	0,09
RMS X_0 Y_0 Z_0 [m]	0,05	0,06	0,06
	0,05	0,06	0,06
	0,03	0,03	0,03
ω φ κ ['']	11	11	12
	11	12	12
	4	5	5

Table 5. Results of aerial triangulation using best filtering and Bingo F in Echallens

The results presented in table 5 certify an increase of the precision of aerotriangulation of blocks for images, which were adequately enhanced. Taking into consideration the prof. T. Schenk's statement that "aerotriangulation's success is the mostly dependant on precision of tie points transfer on following images", my approach to the subject is reasonable as it causes an increase of the precision of fitting tie points on images.

It can be concluded that due to using the best method of enhancement the precision of automatic digital aerotriangulation increases by about 20%.

Echallens block is test block on which were made many tests. Results of automatic digital aerotriangulation made by leading photogrametric centres in Europe is presented.

- Braun J. IFiT (Lausanne) $\sigma_0 = 6,8$ μm
- Hartfiel P. AP (Dortmund) $\sigma_0 = 5,4$ μm
- IGiK (Warsaw) $\sigma_0 = 4,1$ μm

- The result obtained by the author for original block $\sigma_0 = 4,7$ μm
- The result for images enhances using adaptive filter $\sigma_0 = 3,9$ μm

Precision of automatic digital aerotriangulation by using filtration of scanned aerial images has been increased. Application such methods of image enhancement like:
- adaptive filter,
- image enhancement by addition to the original the result of filtration with highpass filter with Butterworth's window in frequency space,
- original image enhancement by addition the result of filtration of original image with Prewitt's mask, of aerial images caused increase of precision of automatic digital aerotriangulation in each of the elaborated blocks.

4. CONCLUSION

Pre-processing of the aerial image is longer by only 4-5 minutes for each aerial image scanned with pixel 21 μm (the time give concerns a processing of the image on a computer Pentium IV 1.5 GHz). Taking into consideration potential of present software's (a possibility of execution of required processes in batch processing), we can assume that there is the possibility of transformation of about 300 aerial images on one computer PIV 1.5 GHz within one day.

Using the method of enhancement the original image with filtration in object space adapting Prewitt's mask firstly we must execute filtration, and then to make association of two images by addition them to each other. Such an operation will take about 10 minutes for one image, so one may process about 140 aerial images within one day.

Using filtration in frequency space we must make transformation to Fourier space, then make there filtration, and then to perform retransformation and to add to original image. The whole procedure takes about 20 minutes for the same working parameters, which were presented above. One may enhance with this method about only 70 aerial images within one day.

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