Digital Terrain Modeling by Image Matching

Tamas JANCSO[a*]

[a]Faculty of Geoinfromatics, University of West Hungary, Szekesfehervar, Hungary

Abstract – The paper reports on the problem, how to optimize the the image matching process after the aerial triangulation. The image matching algorithm is used to measure the tie points on the adjacent photos. Recent autocorrelation implementations cannot offer or suggest the optimal parameters. Therefore we need to investigate it before launching the automatic image matching process for the whole photogrammetric block. In this research the results of 3D modeling including the accuracy requirements for the ground coordinates and exterior orientation elements are demonstrated. For testing large scale (1:8000) scanned aerial photos were used in three different pixels sizes between 7-52 microns. By this way we can compare also the effectiveness and accuracy of software coming from different companies. This comparison can be useful also for the solution providers acting on the photogrammetric market.

Keywords: image matching / scanning resolution / ground resolution / error assessment

1. THEORETICAL CONSIDERATIONS

1.1. Minimal scanning resolution without loss of information

If we want to scan analog arial photos, we need to decide the scanning resolution. We can calculate the minimal scanning resolution by Eq 1 (KRAUS 1993).

$$R_{\min} = k \cdot \frac{1}{2 \cdot VA_a}; \frac{1}{VA_a} = \frac{1}{VA_o} + \frac{1}{VA_p} \qquad \text{(Eq. 1)}$$

Where

$R_{\min}$: minimal scanning resolution (mm),
$k = 0.7$: optimizing factor,
VA_a, VA_o, VA_p : resolution - aggregated, optical, photographic (line pairs per mm).

If we take $\mathrm{VA_a} = 60 \text{linepairs/mm}$, than $R_{\min} = 5.8\,\mu\text{m}$. This scanning resolution is not real in practice and the other problem is that the Eq. 1 doesn't consider the image noise, which can cause loss of accuracy at small scanning resolution.

1.2. Height accuracy of natural points

After performing an arial triangulation we gain the adjusted exterioir orientation elementst and also the $\sigma_{Z(sig)}$ RMS error is calculated from the differences on control points. If we want to calculate the height accuracy of natural points, we need to consider the height uncertainty during the measurement as it is shown at Eq 2.

* Corresponding author: jt@geo.info.hu, H-8000 Székesfehérvár, Pirosalma u. 1-3.

$$\sigma_Z = \sqrt{\sigma^2_{Z(sig)} + \sigma^2_{Z(def)}} = 5 \cdot \sigma_{Z(sig)} \qquad \text{(Eq. 2)}$$

Where

σ_Z : height accuracy of natural points,

$\sigma_{Z(sig)} = 0.07‰ \cdot H$: height accuracy of marked points,

$\sigma_{Z(def)} = 5 \cdot \sigma_{Z(sig)}$: height uncertainty of natural points.

If we plan to compile a digital terrain model on a photogrammetric workstation by image matching of digital stereo-pairs, we can estimate the height accuracy by Eq. 2.

1.3. Scanning resolution and height accuracy

The other way to estimate the height accuracy is to draw a line by Eq3 (Saleh - Scarpace 2000).

$$dZ = p \cdot R \cdot \frac{H}{f} \cdot \frac{H}{B}$$

dZ : height accuracy

p : pointing error factor

R : pixel size (Eq. 3)

H : flight height

f : focal length

B : flight base

For example if we take the values of $p = 2.5, H = 1224\text{ m}, f = 153.0\text{ mm}, B = 731.7\text{ m}$, we get a diagram for several scanning resolutions (*Figure 1*).

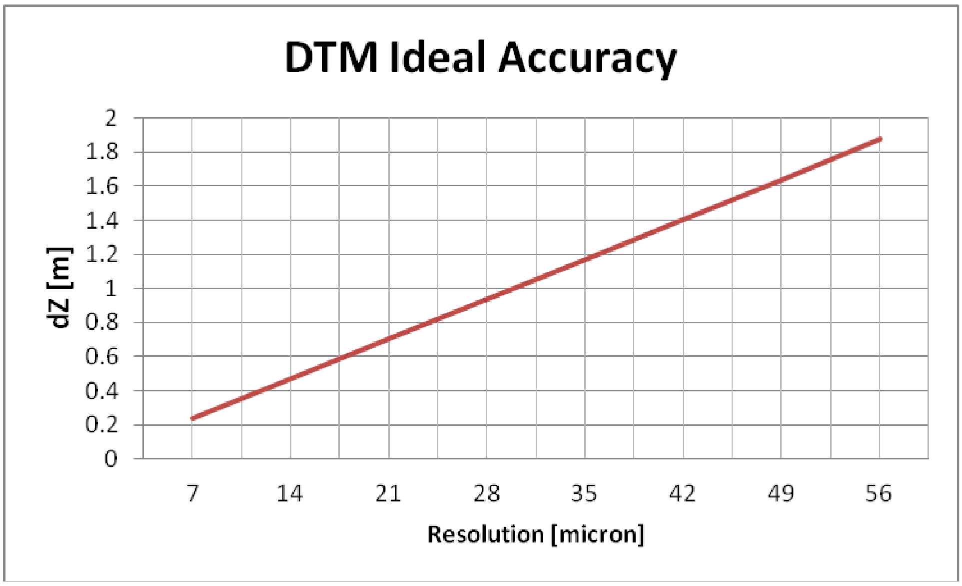

Figure 1 DTM ideal accuracy

2. DATA SOURCES

2.1. Reference data

The test area is located in Hungary, near the town of Szekesfehervar close to the village Iszkaszentgyorgy (*Figure 2*). It is mix of residential area, quarry, forest, meadow and hilly fields. A LIDAR mission was done in 2008 and an aerial Survey is carried out in 2011 (JANCSO – MELYKUTI 2011). From this test area a smaller window of 1780x1000 m was cut out.

Figure 2 Test Area

As a reference data, a 5m GRID was interpolated from the LIDAR point cloud, where the vertical accuracy is about +/- 0.15m (*Figure 3*). On the DTM we can discover a smaller and a larger quarry. A larger forest area is located north of the larger quarry.

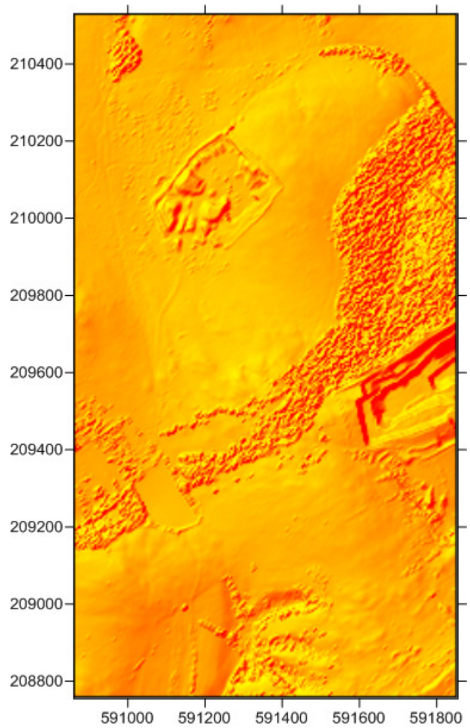

Figure 3 Reference DTM

2.2. Arial images

A series of 5 m GRID models were interpolated from point cloud gained by image matching using a Leica LPS 2011 workstation (*Table 1*).

Table 1 Image matching conditions

Year	2011
Photo Scale	1:8000
Model Area	1780x1000 m
Flight Height	1224 m
Photo Base	731.6 m
Focal Length	153.0 mm
Image Pair	9643-9644
Height accuracy (control points)	0.0869 m
Scannig Resolution (micron)	7,14,21,28
Interpolated Resultions (micron)	32,42, 49,56
GRID Dimension	5x5 m
GRID Interpolation Method	Kriging

The image matching process was done by pixel steps between 1-4 as it is is shown on *Table 2*.

Table 2 Image matching paramters

Scanning resolution	Step	Ground step (cm)
7 micron image	By 4 pixels	22.4
14 micron image	By 4 pixels	44.8
21 micron image	By 2 pixels	33.6
28 micron image	By 2 pixels	44.8
35 micron image	By 2 pixels	56.0
42 micron image	By 1 pixel	33.6
49 micron image	By 1 pixel	39.2
56 micron image	By 1 pixel	44.8

2.3. Gained DTMs and residuals

For each scanning resolution from the points generated from image matching a 5m GRID model was interpolated and the resulting DTM was compared to the the reference DTM. The residual image and list of residuals are genereated by Surfer 9 software. On *Figure 4* the color scale is showing the differences in meters.

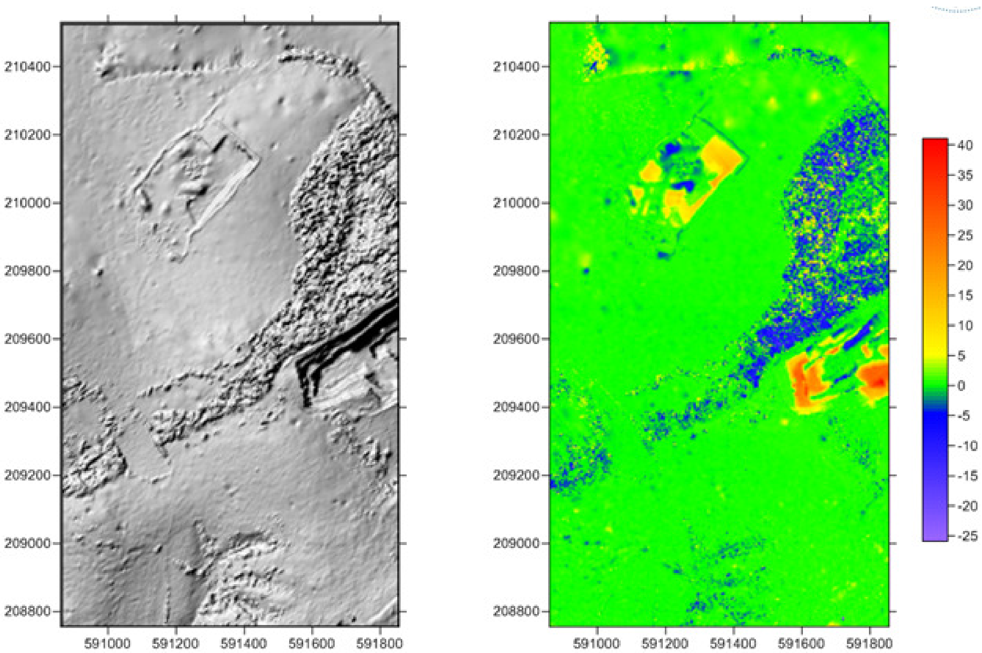

Figure 4 DTM and residual image based on image of 7 micron

3. EVALUATION

3.1. Average RMS errors Statistics

After having the tables of residuals the RMS error is calculated for each resolution (*Figure 5*). The diagram shows that the best resultion is around 14 micron. The 7 mircon image gave a worse result than it was expected. The probable reason is that at high resolution the noise effect is also higher.

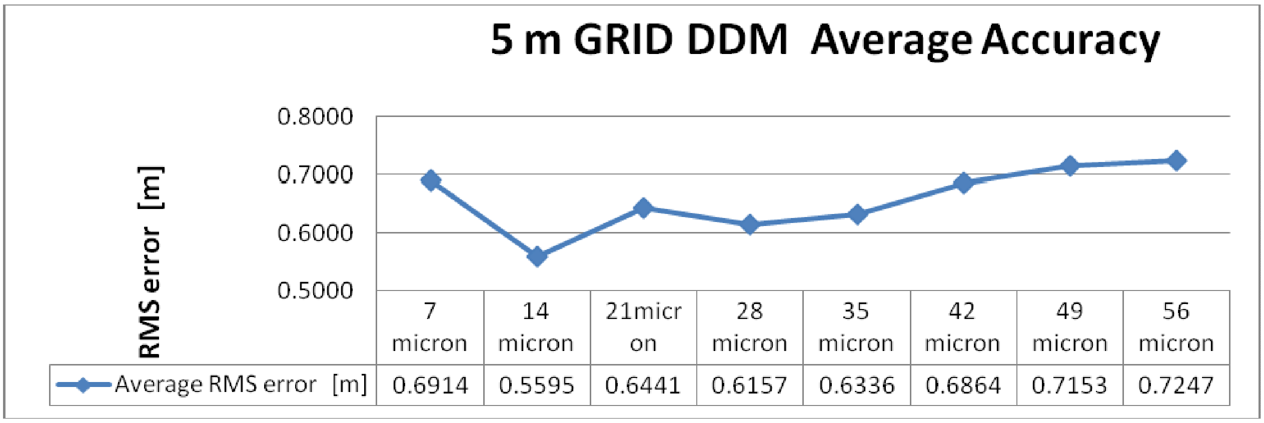

Figure 5 Average accuracy of all DTMs

2.6. Optimal resolution

To find an optimal resoloution we can return to Eq. 3 after having a small modification.

$$R_{op} = k \cdot \frac{1}{2 \cdot VA_a} \quad \text{(Eq. 4)}$$

Where

R_{op} : optimal scanning resolution (mm),

k = 2.5 : optimizing factor,

VA_a : aggregated film resolution (line pairs per mm).

In Eq. 4 the optimizing factor can be found by *Figure 6*, where the ideal and the experimental accuracy is compared. The ideal resolution is around 21 micron.

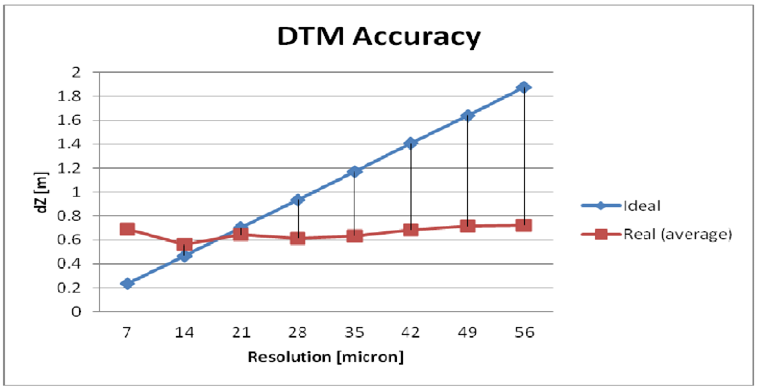

Figure 6 Comprison of ideal and real DTM accuracy

3. CONCLUSIONS

Matching with 7 micron resolution is worse than the matching with14 microns. It means the 7 micron image generates higher noise, which weakens the matching accuracy. If the resolution is higher than 14 microns, the matching error doesn't grow rapidly. Ideal scanning resolution is between 14-35 microns. No big difference in accuracy, therefore a good compromise is a 28 micron image.

Acknowledgements: I wish to thank for TÁMOP 4.2.1.B-09/1/KONV-2010-0006.

References

KRAUS, Karl (1993): Photogrammetry, Volume 1, Fundamentals and Standard Processes, Fourth Edition, Ferd. Dümmler's Verlag, Bonn, ISBN 3-427-78684-6, pp. 346-347

JANCSO, Tamas, MELYKUTI, Gabor (2011): Comparison of Digital Terrain Models Gained by Different Technologies, Procedings IEEE International Conference on Spatial Data Mining and Graphical Konwledge Services (ICSDM 2011) in conjuction with Eighth Beijing. International Workshop on Geographical Information Science (BJ-IWGIS 2011), China, Fuzhou, June 29- July 01, pp. 324-329

SALEH, Raad, SCARPACE, Frank (2000): Image Scanning Resolution and Surface Accuracy; Experimental Results, International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B2, Amsterdam, pp. 482-485