QUALITY ASSESSMENT AND IMPROVEMENT OF ALS DATA ACQUIRED WITHIN THE PROJECT OF NEW HYPSOMETRY GENERATION OF THE CZECH REPUBLIC

Radek, FIALA[1]

[1]Department of Mathematics, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 22, 306 14, Plzeň, Czech Republic

fialar@kma.zcu.cz

Abstract

Quality assessment of new digital terrain models covering the entire area of the Czech Republic is a prerequisite for their successful application in geosciences and various branches of national economy as well.

The paper presents “method of accuracy analysis of ALS points in close neighbourhood of check points” that is used for quality assessment of ALS data acquired within the Project of new hypsometry generation of the Czech Republic. The method respects considerable disproportion between number of ALS points and geodetically measured check points on control surfaces. Results of the method applied on check surfaces covering one third of the state territory is presented. The results are not related to final products of the Project (neither DMR 5G nor DMP 1G).

Another method leading to homogeneity improvement of ALS data is presented. The method assumes significant cross overlaps of neighbouring ALS strips. Its application removes local systematic height differences of ALS strips so that all details contained in the ALS data are preserved and no smoothing is performed. The same method with a minimal modifications can also be used for adjustment of neighbouring ALS blocks in areas of their overlaps. However the method is not intended for removing of any gross errors in ALS data. Within the Project of generation of new hypsometry of the Czech Republic the method has been applied in almost 20 % of the state territory.

Keywords: digital terrain model, DTM quality assessment, airborne laser scanning, ALS strip adjustment

INTRODUCTION

Up to now the only digital terrain models (DTMs) covering the entire area of the Czech Republic are: DTM of Fundamental Base of Geographic Data (DTM ZABAGED®) maintained by the Czech Office for Surveying, Mapping and Cadastre and Digital Terrain Model of 3rd generation (DMR 3G) maintained by the Ministry of Defense. The DTM ZABAGED® originated from contour lines of Base Map of the Czech Republic in scale 1 : 10,000 periodically updated by means of stereo photogrammetry. The DMR 3G originated from stereo photogrammetric measurement only. Vertical accuracy of both DTMs is very similar: 1–2 m in open terrain and built-up areas, respectively 2–7 m in forested areas (Brazdil, 2009).

For many purposes, accuracy of the existing DTMs seems to be unsatisfactory. That is why significant improvement or generation of a new DTM was considered. As a result the Project of new hypsometry generation of the Czech Republic (Project) was prepared. There are three participants of the Project: the Czech Office for Surveying, Mapping and Cadastre, the Ministry of Defense and the Ministry of Agriculture. Important results of the Project will be Digital Terrain Model of 4th and 5th generation (DMR 4G, DMR 5G) and Digital Surface Model of 1st generation (DMP 1G). Anticipated vertical accuracy of the most precise DMR 5G is 0.18 m in open terrain and 0.3 m in forested areas. Similar accuracy of the DMP 1G will be 0.3 m in case of objects with well defined surfaces (e.g. building roofs) and 0.7 m in case of other objects (Brazdil, 2009).

Accuracy assessment of the data acquired within the Project is based on hundreds of control surfaces covered by grid of check points. The control surfaces are almost horizontal and vertically well defined areas (e.g. football playground). ASPRS recommends at least 20 check points in each control surface (ASPRS, 2004). The control surfaces used for accuracy assessment in the Project meets and often surpass this recommendation (100 check points in one control surface is common). Errors computed from data covering the control surfaces have to be considered as errors not including additional errors due to terrain slope and land cover (and coordinate transformation/conversion if applicable).

METHOD OF ACCURACY ANALYSIS OF ALS POINTS IN CLOSE NEIGHBOURHOOD OF CHECK POINTS

For needs of the Project a new method of accuracy analysis of ALS points in close neighbourhood of the check points has been developed in Department of Mathematics of the University of West Bohemia in Pilsen. It is based on specific properties of control surfaces and check points. Particularly, the method requires a horizontal neighbourhood of a check point within the chosen diameter. The method respects a considerable disproportion between number of ALS points and geodetically measured check points on selected control surfaces. The method assumes that point coordinates are expressed in compound coordinate reference system including heights in any height reference system. Results of the processing are values of systematic error and random error, of course with respect to accuracy of check points.

The computation starts with discovering a set L_i of ALS points in circular neighbourhood of a check point r_i for all check points r_i, $I = 1, \ldots, n$, in the control surface. The points L_i must not lay outside the control surface. Then a set D_i of height differences between the check point r_i and ALS points in set L_i is computed. Union $D = D_1 \cup D_2 \cup \ldots \cup D_n$ contains height differences between all check points and ALS points in their neighbourhood. The systematic error c_h is then computed as an average of the set D. Random error σ_h is computed as a sample standard deviation.

The estimation of random error σ_h allows detection of blunders. The method has been intended for fully automatic processing so the blunder detection must be automatic, too. Usual criterion "$k \,.\, \sigma_h$", assuming normal distribution of errors, has been used. The value of k should depend on size of D and on a selected probability of false detection of ALS point to be a blunder. However, the value of $k = 3$ is usually used. After detection of blunders, the computation of errors is repeated without the blunders.

METHOD FOR HOMOGENEITY IMPROVEMENT OF ALS DATA

In the course of ALS data processing in the Project, some imperfection in measuring ALS points heights has been detected. It results in local systematic height differences between overlapping ALS strips even after calibration of orientation parameters. The differences are small enough not to violate the accuracy assumptions but it could be serious in some applications, e.g. in visualization of flat areas. Figure 1 shows digital surface model of a storehouse created from two strips of ALS data with 0.08 m average height difference (in most areas the height differences between ALS strips were smaller). Further described procedure eliminates those height differences as illustrated in figure 2.

The process of eliminating local height differences between ALS strips (strip adjustment) is based on a difference model describing those height differences. Such difference model is computed for each pair of adjacent strips. The values of difference model are then split between two strips involved through the system of weight functions. Cross overlap of ALS strips is nearly 50 % in the Project. Therefore, most of the scanned area is covered by data in two adjacent ALS strips. Main steps of strip adjustment are:

- computing of initial values of the difference model,
- cleaning and smoothing of the difference model,
- adjustment of ALS point heights according to values in the difference model.

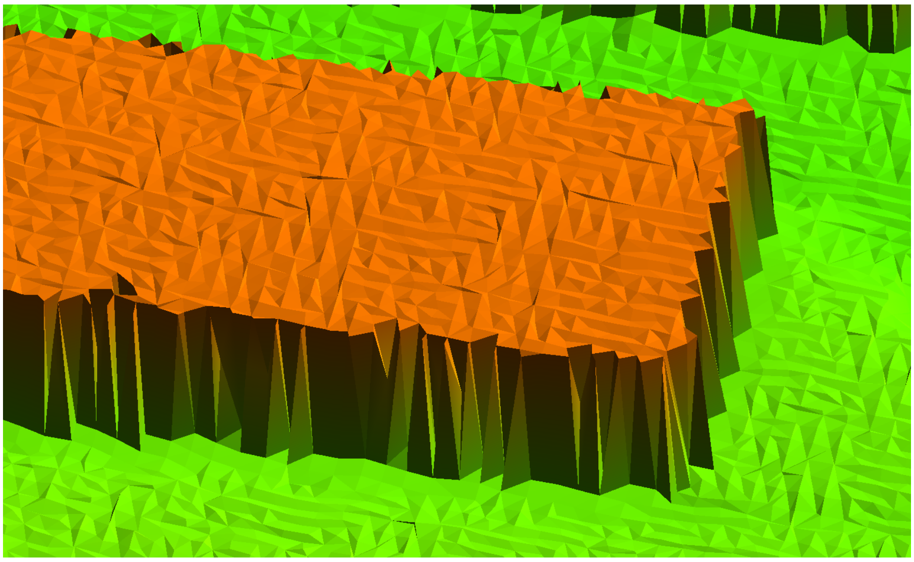

Fig. 1. Digital surface model from two overlapping ALS strips

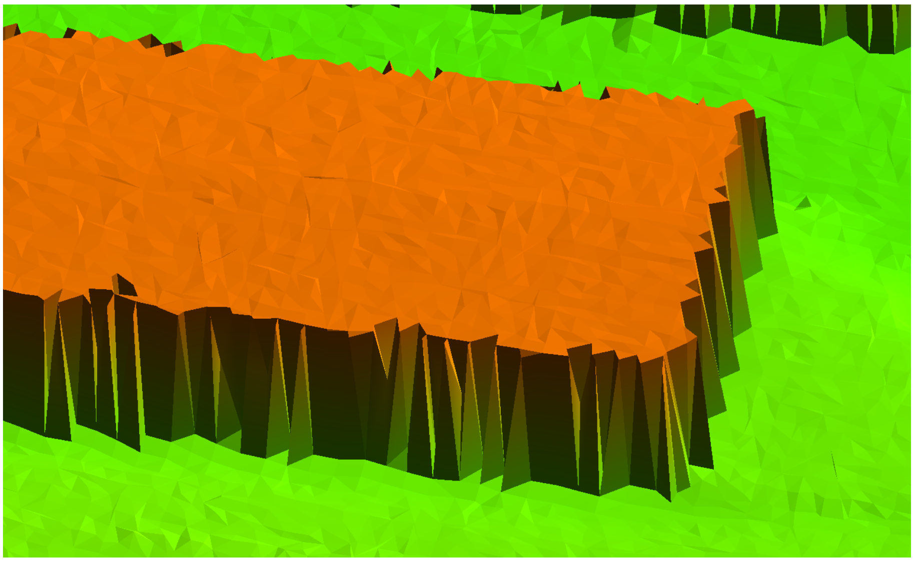

Fig. 2. Digital surface model from two overlapping ALS strips with adjusted height differences

Computing of initial values of the difference model

The ALS points in both strips are divided into the identical rectangular grid. For each cell of the grid estimations of mean height and standard deviation of heights of the ALS points is computed. A robust approach using lower and upper quartiles is used assuming symmetric probability distribution of point heights for mean height estimation computation and normal probability distribution for standard deviation estimation computation. Additionally a weight of the cell in each strip is computed depending on point density in the cell and estimation of standard deviation. The initial value of each difference model cell is computed as a difference of estimations of mean ALS point heights in both strips. The weight of the cell is set to a minimum of cell weights in both strips. From now on, the cell values and weights can be regarded as pixels of an image. Example of a difference model with pixel size 5 × 5 m can be seen in figure 3 (a cut 2 km long). Red (respectively blue) colour denotes positive (negative) values, colour saturation denotes absolute value of the cell. In light green areas, the values are too great or too less (> 0.2 m in this case; e.g. in forest areas). In white areas there are no data available. The dotted lines are planned flight lines.

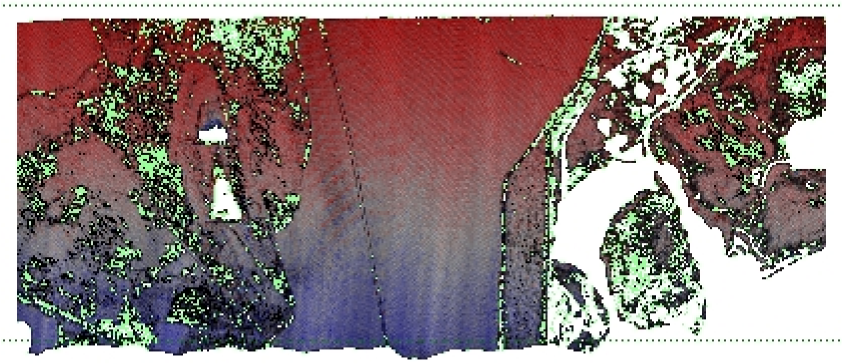

Fig. 3. Initial values of a difference model

Cleaning and smoothing of the difference model

Cleaning and smoothing uses well known algorithms of image processing that were generalized in order to encompass weights of the cells in the calculations. At first, an median filter is applied to the difference model. This filter removes extreme values in the difference model without influencing values of neighbouring cells. After applying the median filter the difference model still contains height difference discontinuities. Hence, a gaussian filter is applied to the difference model. This type of filter smooth out possible height discontinuities. Then pixel weights are removed and the image is filtered using the gaussian filter once again. The resulting difference model is very smooth as can be seen in figure 4.

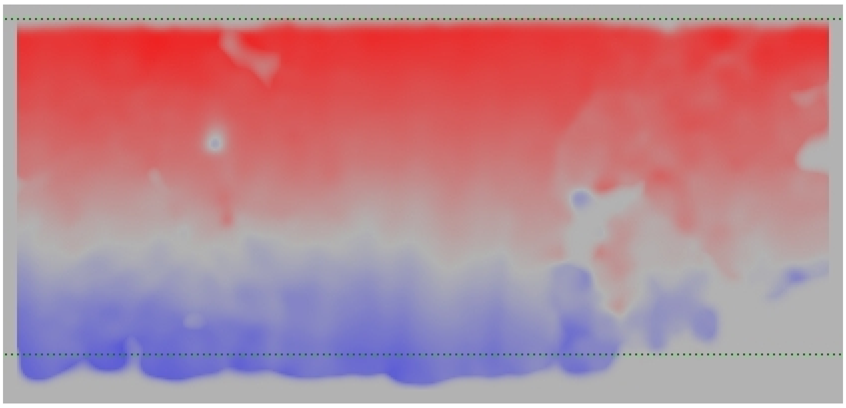

Fig. 4. Smoothed difference model

Adjustment of ALS point heights according to values in the difference model

The difference model contains characteristic height differences between two overlapping ALS strips. To eliminate those differences, the heights of points in both strips are corrected so that in particular position the sum of corrections in both strips is equal to value of difference model. Proper splitting of corrections between both strips is ensured by the weight functions. In the center of the strip (more precisely: under the planned flight line) the weight is 0. It means that there are no height correction in the center of the strip. At the edge of the strip (under the flight line of adjacent strip) and farther the weight is 1. The weight function should meet several requirements to minimize strip height differences and to prevent inducing terrain break lines by adjusting height of ALS points. One of the simplest weight function meeting all requirements can be expressed as a polynomial of degree 3.

As an illustration of the effect of the method, the difference model without any smoothing has been computed after strip adjustment. This difference model is shown in figure 5.

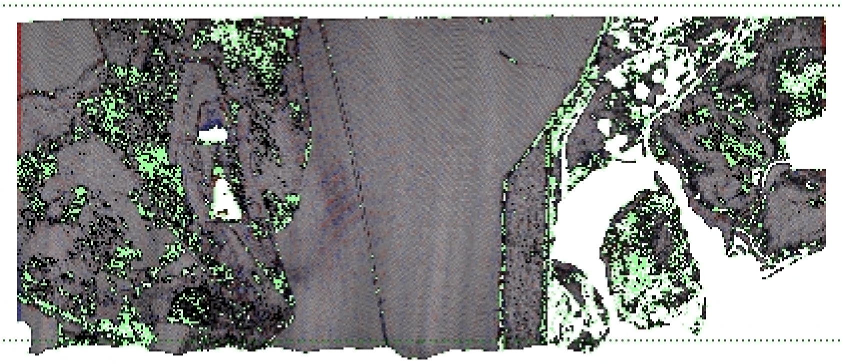

Fig. 5. Difference model (non-smoothed) after strip adjustment

This method of strip adjustment was applied by the Land Survey Office in Pardubice in almost 20 % of state territory in the course of the year 2011 with following parameters: pixel size 20 × 20 m, size of median filter 180 m, σ of Gaussian filters 75 m.

RESULTS AND DISCUSSION

The method of accuracy analysis was implemented and used by the Land Survey Office in Pardubice. Analysis computed for 185 control surfaces covering approximately 1/3 of the state territory (denoted as Pásmo Střed) using 1 m perimeter of neighbourhood results in overall values: systematic error c_h = −0.033 m and random error σ_h = 0.048 m.

The strip adjustment method was applied at about 60 % of Pásmo Střed (15,400 km²). Though the strip adjustment method is not intended for removing errors, the values of both overall systematic error c_h and overall random error σ_h decreased after strip adjustment as shown in table 1. These results has been computed using the method of accuracy analysis of ALS points in close neighbourhood of check point using 98 control surfaces located in area where adjustment was applied. Changes of the errors for individual control surfaces are depicted in figure 6. As can be seen, random errors σ_h calculated for most control surfaces decreased after strip adjustment. Unexpectedly, the value of systematic error c_h decreased too. With respect to weight function role in strip adjustment, a dependency of systematic error c_h on distance from flight line can be the reason for decreasing of systematic error c_h.

According to Karel & Kraus (2006) the accuracy of a DTM from ALS data is influenced mainly by ALS point density and terrain slope. Assuming point density of 2.7 points/m² in open terrain and 0° terrain slope (as on control surfaces) the predicted value of random error σ'_h = 0.037 m, thah is slightly lower than the computed value. The predicted value of random error is almost same as a computed value of random error after strip adjustment (0.035 m). The results of accuracy assessment agree with theoretical expectations. According to Šíma (2011) the projected overall height accuracy of the DMR 5G is reachable considering actual distributions of terrain slopes and forested areas in the Czech republic.

Table 1. Overall values of systematic error c_h and average error σ_h before and after strip adjustment (98 control surfaces located in area where the strip adjustment was applied)

	Before strip adjustment	After strip adjustment
Overall systematic error c_h	−0.033 m	−0.020 m
Overall random error σ_h	0.046 m	0.035 m

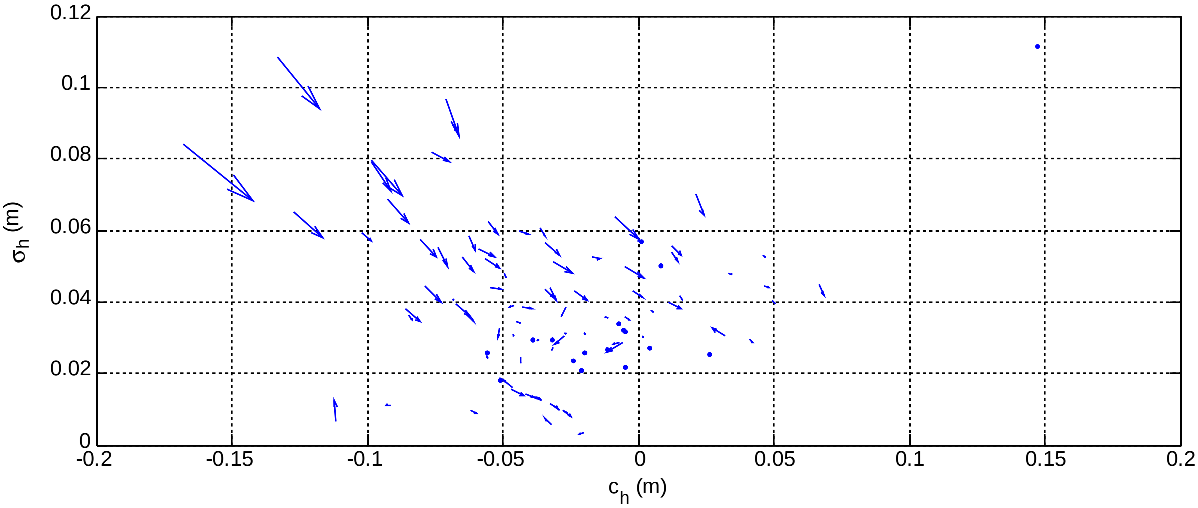

Fig. 6. Changes of systematic error c_h and random error σ_h before and after strip adjustment (98 control surfaces located in area where the strip adjustment was applied)

CONCLUSION

The method of accuracy analysis of ALS points in close neighbourhood of check points used for quality assessment of ALS data in the Project of new hypsometry generation of the Czech Republic was introduced. Using this method overal values of systematic error $c_h = -0.033$ m and random error $\sigma_h = 0.048$ m was computed for 185 control surfaces covering approximately 1/3 of the state territory (Pásmo Střed).

The principles of method of strip adjustment has been introduced. The method eliminates local height differences between two adjacent strips ensuring that no induced terrain break lines arises. Further, all details of the relief within the ALS data are preserved because no smoothing is applied to the ALS data. Overall random error $\sigma_h = 0.046$ m computed for 98 control surfaces located in area where the strip adjustment was applied decreased to $\sigma_h = 0.035$ m after strip adjustment. Unexpectedly, value of overall systematic error decreased from $c_h = -0.033$ m to $c_h = -0.020$ m too.

REFERENCES

Brázdil, K. (2009) Projekt tvorby nového výškopisu území České republiky. In *Geodetický a kartografický obzor*, 7, p. 145–151. ISSN 0016-7096

Karel, W, Kraus, K. (2006) Quality parameters of digital terrain models In *EuroSDR Official Publication 51*. Utrecht: Gopher, 2006. p. 87–93. ISBN: 90-5179-491-6.

Šíma, J. (2011) Příspěvek k rozboru přesnosti digitálních modelů reliéfu odvozených z dat leteckého laserového skenování celého území ČR. In *Geodetický a kartografický obzor*, 5, p. 104–107. ISSN 0016-7096

ASPRS (2004) Guidelines Vertical Accuracy Reporting for Lidar Data. ASPRS. http://www.asprs.org/Division-General/LD-Airborne-Lidar-Committee-Downloads.html.