ANALYSIS OF AIRBORNE LASER SCANNING DATA AND PRODUCTS IN THE NEUSIEDLER SEE PROJECT

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KEY WORDS: Aerial laser scanning, Neusiedler See Project, DTM, quality, local quality parameters, intensity, normalization, classification.

ABSTRACT:
The paper is a condensed presentation of the experimental part of my graduation project (Bitenc, 2006), which I carried out at the Institute for Photogrammetry and Remote sensing (I.P.F.) at the Vienna University of Technology during my Erasmus exchange program. The main topic is attractive, useful and advanced technology - airborne laser scanning, which was used in the Neusiedler See project in order to enable hydrological analyses. The aim of this project, which was part of the international SISTEMaPARC project in the framework of the transnational European project INTERREG IIIB CADSES, was refilling drained natural basins with water, so centimeter accuracy of digital terrain model (DTM) was required. Its high relative and absolute accuracy was obtained by using the post-processing method. The paper presents analysis of DTM quality with local quality parameters. According to the results the DTM of the Neusiedler See National Park reaches 4 cm accuracy in height. The second analysis, described in this paper, aims to investigate intensity values measured with laser scanners. Intensity is a side product of ALS, but could be very useful for recognizing the scanned objects, while it gives semantic information directly to the 3D data. The possibility to use it for land cover identification and classification was investigated. Some land cover is separable with intensity data, but it was discovered that just ALS data are not sufficient.

1. INTRODUCTION

Relatively new method of remote sensing - airborne laser scanning (ALS), has recently been greatly improved and developed, which makes it very useful in a wide range of applications. On the one hand better sensor technology sets up different systems, which provide a user with a lot of data in a short time, while on the other hand newly developed and improved post-processing methods enable more automated and exact calculation of results e.g. DTM, DSM, 3D city model. Therefore results are used in a variety of different applications such as forestry, urban planning, hydrological hazards, archeology, coastal monitoring, roads, power lines and telecommunications survey, GIS and cartography, 3D cadaster … In the case of the Neusiedler See project, ALS was used to provide accurate and up-to date DTM for hydrological analyses.

In the 20th century an over-exploitation of groundwater and wide-spread artificial draining caused drastic changes to the natural park, so today just 25% of the water surface area still exists. In order to protect and restore the area, new research was done, based mainly on ALS data. Details on the first research within the transnational project INTERREG IIC can be found in Horvath (2001) and Herzig et al. (2002) and the second, which was done within the discussed project, in Attwenger and Chalaupek (2006), Attwenger et al. (2006) and Chaupelek (2006). The exact location of the project, which is split between Austria and Hungary, can be seen on Figure 1.

After the data for the Neusiedler See project were acquired by the company TopScan, the post-processing started at the I.P.F, home developed algorithms were used to contribute an accurately modelled DTM. While the DTM is most often used and is therefore the most important result of ALS, it is necessary to provide a user with information about its quality. According to the known quality, which consists of components like precision, accuracy and reliability, the optimal decision could be made. Those metadata could be given with different quality parameters. In this analyze of a Neusiedler See's DTM the **local quality parameters** were calculated with a step-by-step empirical stochastic approach, which gives grid point related quality parameters of DTMs. The method was developed at I.P.F. and is described in Karel (2005), Karel and Kraus (2006) and Karel et al. (2006).

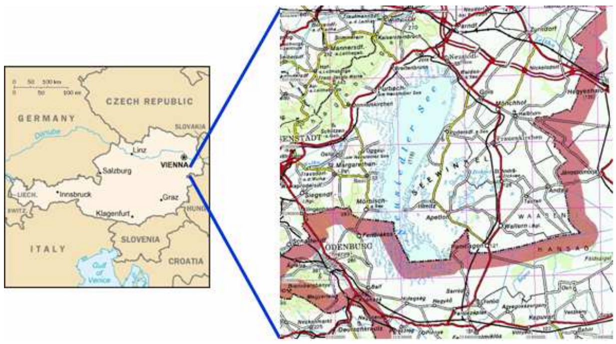

Figure 1. Project area – national park Neusiedler See (Attwenger, 2005).

The second analysis done on the Neusiedler See data aims to investigate intensity values of the reflected laser light. ALS technology gives accurate 3D data of the scanned surface, but the information about a type of scanned objects is questionable. Time-consuming post processing algorithms help us to identify terrain, buildings and other objects. To make it faster and easier the objective of this analysis was to identify land cover types that occur on the scanned area like fields, meadow; roads and vineyards and (automatically) classify laser points regarding to intensity values. The main obstacle to using intensity directly is the fact that the measured values are a complicated function of many influencing factors. State of the art experimental analysis on the intensity values can be found in Song et al. (2002), Lutz et al. (2003) and Hasegawa (2006). Since now the intensity values are primarily used for visualization of scanned area (colour coded image), but in future applications like searching for homologues features, improving the classification and the extraction of features, use in the forestry etc. will be developed.

2. THE PROJECT NEUSIEDLER SEE

2.1 ALS data acquisition

The aerial mission was done on 24. and 25. November 2004. The scanned area of the Neusiedler See/Seewinkel national park measures 340 km^2 and consists of 57 strips. Six of them are cross strips, which should be scanned at the ends of the block. Actually two are missing on the southern and eastern part of the project area (see Figure 2). Cross strips are essential for joining strips together in one model and help to improve relative orientation. The point density, which greatly influences the accuracy of computed products, is 1,5 points per square meter.

The sensors used for ALS data acquisition and their properties are summed up in Table 1. Some parameters about flying mission have to be defined beforehand and considered during flight, so at the end the desired data is available for post-processing.

Flying parameters	
planned flying speed	65 m/s ~ 126 Kn
planned flying height above the ground	1000 m
planned strip distance	450 m
Measurement system – ALTM 2050	
laser repetition rate	50.000 Hz
max. scan angle	20 deg
Scan frequency	25 Hz
planned strip width	725 m
planned strip overlap	275 m (30%)
Digital metric camera – Emerge DSS	
Array size	4.092 x 4.077 Pixel
Pixel size	0,009 mm
Filter array	True colors
Lens	Zeiss Distagon 55,0 mm, 36° FOV
planned disposition distance	325 m
Quantization	16 bit
Resolution on ground	0,17 m x 0,17 m

Table 1. Parameters of planned flight and used sensors (Laserscannermessung …, 2005).

At the same time as the flight mission, GPS measurements with the frequency 1 Hz were done on 4 ground points – KT602-79, KT460-79, KT441-78A2 and KT135-109.

2.2 Terrestrial measurements

For the Neusiedler See project terrestrial measurements were carried out by civil engineer dipl.-Ing. Horvath, Neusiedl am See in August 2005. They are essential for more precise fitting of ALS strips together and help to improve absolute orientation. The best solution is obtained, if the control area has a minimum of three tilted planes with different aspect (Kager, 2004). In the case of the project 12 control areas were measured with tachometry on the basis of GPS net. Because of a lack of tilted planes in the south-eastern area of the project, two horizontal planes and additionally height points were measured (Figure 2).

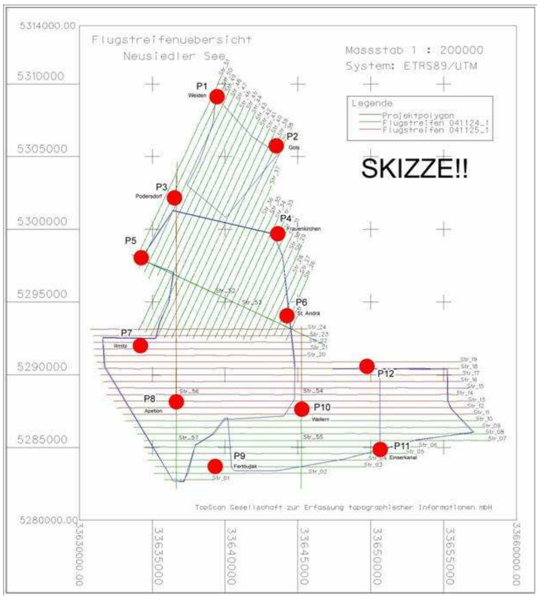

Figure 2. Laser scanner strips - red and green lines and the control areas - red dots (Attwenger, 2005).

2.3 Processing of the data

The first processing steps were done in Topscan and are described in detail in the technical report of the project (Laserscannermessung …, 2005). They joined the ALS data of three main technologies (GPS, IMU and laser scanner) and did the so called georeferencing. The results were 3D coordinates of laser points in the reference coordinate system WGS84, which were then transformed into ETRS89 and Gauss-Krüger M34 coordinate system and interfered to the I.P.F. Vienna for DTM computation. Tasks done at the I.P.F. Vienna were (see Attwenger and Chalaupek, 2006, Attwenger et al., 2006):

1. Quality check
2. Fine georeferencing
3. Height correction for geoid undulation
4. Calculating the digital surface model (DSM)
5. Calculating the digital terrain model (DTM)
6. Joining the Austrian and Hungarian DTM
7. Transformation from ETRS89 to national coordinate system MGI

Computer programs used for processing were SCOP++, Orient and other program modules developed at the I.P.F. Vienna.

3. ANALISING THE QUALITY OF DTM

3.1 Local quality parameters

In contrast to global quality parameters, which are valid just for a certain measuring technique and provide just one value for the whole area (see Karel and Kraus, 2006), the local quality parameters give much more detailed information about DTMs' quality. In order to consider all factors that influence DTM computation and modeling, and to obtain detailed estimation of DTM quality, I.P.F. Vienna developed a method for the derivation of the height accuracy of each grid point. This approach has the following properties:

- It may be used to analyze DTMs existing beforehand.

- It is independent of the interpolation method.
- In the computation of quality parameters, the original data are used.
- Quality parameters have the resolution of the individual grid points.

The factors that influence accuracy of DTM, that we are looking for, are according to the I.P.F. Vienna approach:

- The number and alignment of the neighboring original points.
- The distance of original points to the respective grid point.
- The terrain curvature in the neighborhood of the grid point.
- The accuracy in height of the original points.

They form the input of a simple interpolation method for the estimation of the accuracy of each grid point (see the equation in Kraus et al., 2005). The final result (DTM quality) as well as intermediate results (influencing factors or so-called quality parameters) is easily and clearly visualized. In such a manner the precision of DTMs is confidence-building for end users.

3.2 Calculation and results

The calculation of local quality parameters for Neusiedler See DTM was done with the program *sigmaDTM.exe*, developed at the I.P.F. Vienna. Input files are **.dtm*, with the DTM's grid points, and **.xyz*, with original terrain points. From the whole project's area I chose 5 squares with a side size of 2 km. Each of them has a different prevailing feature like rush, village, vineyards, fields and wood. Besides the computation of DTM quality, the objective was to compare quality parameters according to the different features.

The following five models show the local quality parameters of each grid point. Visualization was done within the program SCOP and is shown just for the *Village* area.

The model of minimum distance between each grid point and its nearest original point (

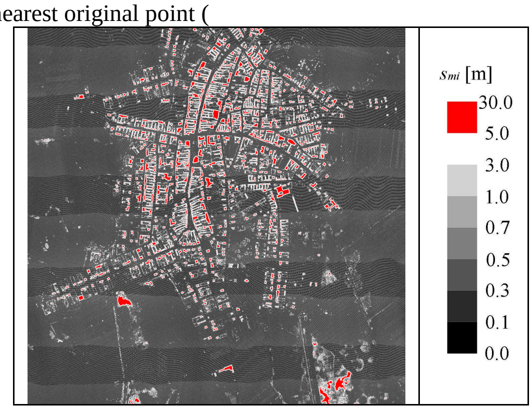

Figure 3) shows areas without data (marked red on the

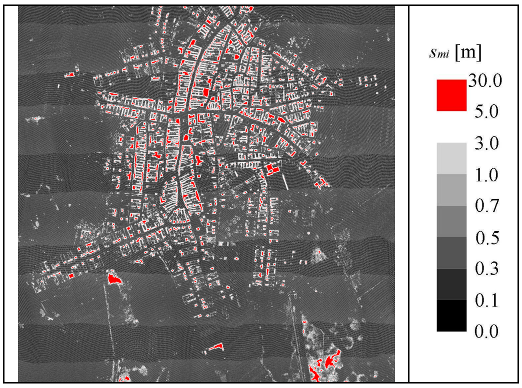

Figure 3,

Figure 5, Figure 6 and Figure 7). These areas are useless and must be pointed out to users. They most often occur in areas with buildings and dense vegetation.

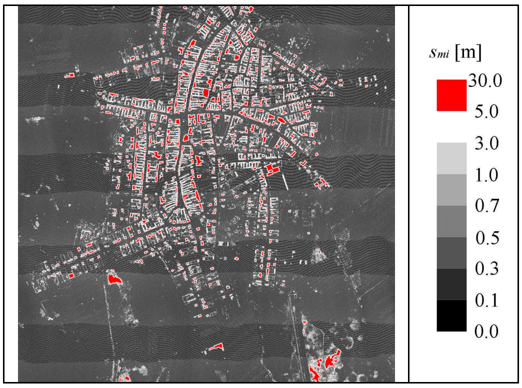

Figure 3. The colour-coded model of minimum distance.

The model of maximum main curvature at each grid points (

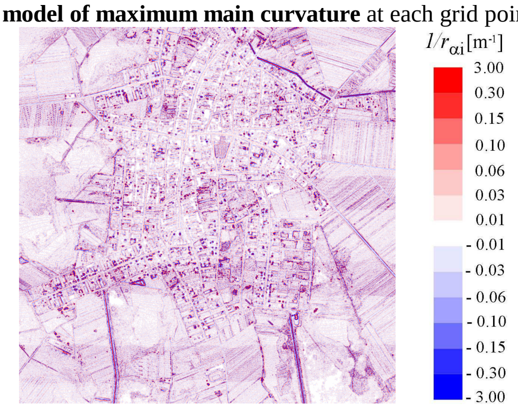

Figure 4) shows tiny terrain characteristics like not eliminated low vegetation, outlines of buildings, ditches, furrows … Red casts show relatively higher areas (DTM goes up) and blue casts relatively lower areas (DTM goes down).

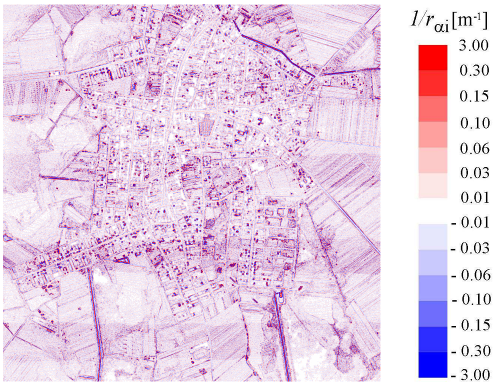

Figure 4. The colour-coded model of maximum main curvature.

The model of height accuracy of original points (RMSE, see

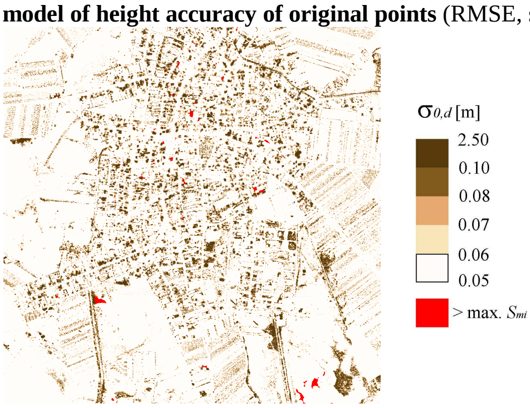

Figure 5) has an a-priori defined lower limit, which in this case is 5cm. It is determined regarding to post-processing steps, which include quality checks and fine georeferencing of ALS strips. The best accuracy is reached where the terrain is flat and without vegetation or big buildings (area with fields).

Figure 5. The colour-coded model of RMSE.

The model of weight coefficient (Figure 6) has values lower than 1, which means that the accuracy of DTM will be higher than the accuracy of the original points, which is actually our aim.

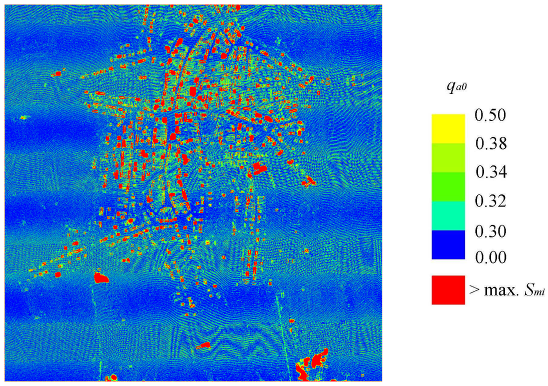

Figure 6. The colour-coded model of weight coefficient.

The model of height accuracy of the DTM (Figure 7) is the most important result and shows the spatial variation of sigma DTM. The computation employs the reference standard deviation (

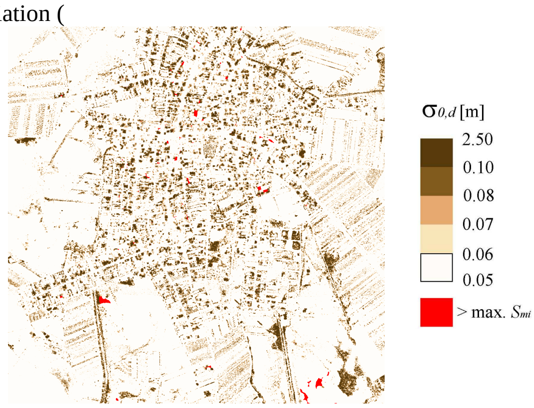

Figure 5) and the weight coefficient (Figure 6). In this analysis the sigma DTM varies from 0 cm to ±4 cm.

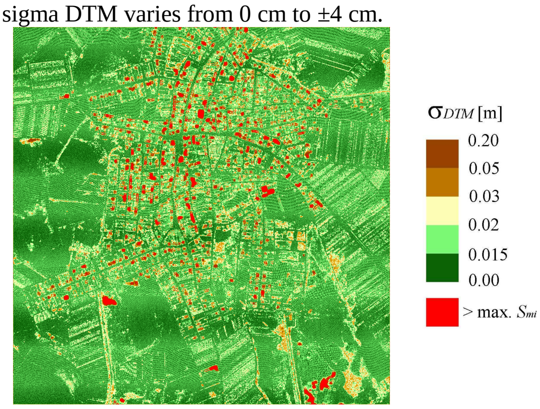

Figure 7. The colour-coded model of sigma DTM.

4. ANALISING THE INTENSITY DATA

4.1 Intensity measurements

Because the 3D lidar point cloud itself does not include information about the object types on which points are located, intensity measurements are important data for identification of objects and phenomena in physical space. Colour-coded intensity value image confirms this, as particular objects (asphalt road, grass, building etc.) could be recognized. Intensity values have no unit and are relative measurements. While the definition in Song (2002) says intensity is a ratio between the received and transmitted strength of laser light, the equation for received power in Hug and Wehr (1997) can be used and simplified, so measured intensity could be calculated as,

$$I_m \approx \frac{P_r}{P_t} = \frac{\rho * \cos\xi}{R^2} * konst. \quad (1)$$

Where
I_m … measured intensity
P_r … strength of received signal
P_t … strength of transmitted signal
R … measured range
ρ … reflectivity
ξ … angle of incidence

Therefore intensity depends on measured range, angle of incidence, which is a function of normal on terrain and scan angle, and reflectivity, that is defined for a certain material for the laser light wavelength (see the table in Wagner, 2005). The measured intensity must be normalized for these factors in order to be used for identification and classification of the scanned features.

4.2 Data

Data available for the analysis were lidar points by strips (position and intensity) and raw digital photos, made simultaneously using laser scanning. From 3D coordinates of lidar points the DTM and DSM were calculated. The first one gives information on how the terrain is changing and shows relatively flat area – heights are changing just by 15 cm. The second model was used as an underlying layer, which adds the height perception to the intensity data, so we can separate vineyards, objects, vegetation etc. For the research of a correlation between intensity and main influencing factors (equation **Napaka! Vira sklicevanja ni bilo mogoče najti.**) additionally polar coordinates were calculated in the program Orient.

4.3 Analyze and corrigenda of measured intensities

The objective of the analysis was normalizing the intensity to use it for identifying land use, so we were looking for a function *f* in equation 2.

$$I_m = f(R, dA(\xi), \rho) \quad (2)$$

Range (R) is known for each lidar point from polar coordinates. Incidence angle (ξ) is a parameter of the footprint size (dA), which influences intensity. While we analyze intensity for terrain features (fields, meadow; roads and vineyards) and in the case of the Neusiedler See project the scanned terrain is relatively flat, it can be simplified that incidence angle is equal to the scanned angle. Furthermore the scanned angle is a parameter of the measured range, so we can neglect its influence. The biggest influence on measured intensity has reflectivity, which we do not know. Also theoretical values, which are typical for certain materials, can not be taken into consideration, while we are not able to extract intensity values for a certain feature eg. fields. But since the reflectivity is the same for one material or at least similar for one land use, we presumed that points from two overlapping strips, lying less than 10 cm apart, have the same intensity value (Figure 8). The footprint is a minimum 20 cm in diameter.

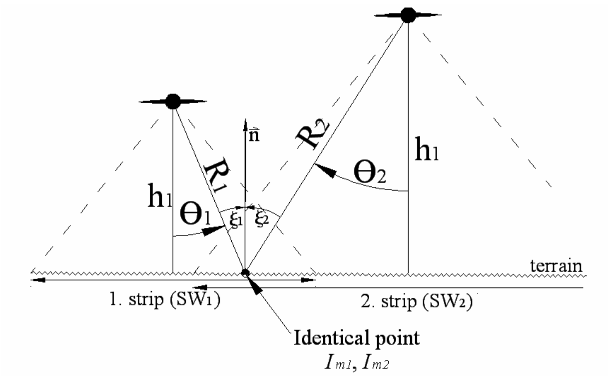

Figure 8. Geometrical relation between variables for identical points.

The identical points were computed in several areas of overlapping strips with the program Matlab. While the measured intensities for identical points are not the same, we analyzed the difference of measured intensities according to changes in range (equation 3).

$$\Delta I_m = f(\Delta R),\ \Delta\rho = konst. \quad (3)$$

The empirical analysis of different areas showed linear dependency between variables ΔI_m and ΔR (Figure 9).

The equation (3) can be rewritten as,

$$\Delta I_m = a * \Delta R + b \quad (4)$$

Now we estimated parameters a and b with the least-squares method and computed corrections $\overline{\Delta I(\Delta R)}$ of the measured intensity for the rest of the lidar points in the corresponding strip. Because the correction is relative, since we used variable ΔR, intensities of one strip do not change (master) and intensities of another strip (slave) are increased or decreased for the corrections.

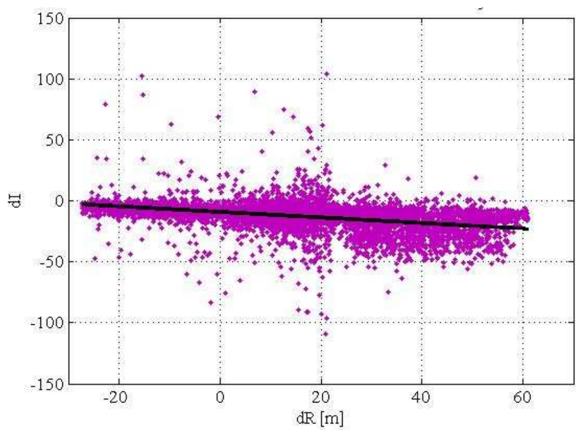

Figure 9.The linear dependency of intensity differences on range differences.

If $\Delta I_m = I_{m,2} - I_{m,1}$, then the normalised intensities can be calculated as,

1. possibility I_2 (2. strip is master)

$$I_1 \rightarrow I_1^n = I_{m,1} + \overline{\Delta I(\Delta R)} \quad (5)$$

2. possibility I_1 (1. strip is master)

$$I_2 \rightarrow I_2^n = I_{m,2} - \overline{\Delta I(\Delta R)} \quad (6)$$

4.4 Classification

After the normalization of intensity values for the average range we continued with the classification process. But it turns out to be unsuccessful. The figure below shows an example for the meadow classification – besides meadows, there are also roads and other areas and points that lies on fields.

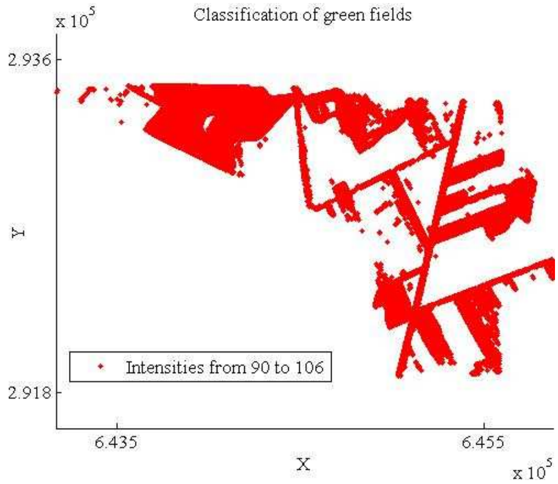

Figure 10. Example of intensity image extracted for values from 90 to 106.

The described method of relative normalization with the help of identical points gives a more homogeneous and a clearer intensity image, but the intensity within certain land use does not change much. Normalized intensities of slave strips are just shifted according to the master strip, so the interval of intensity values for certain land use is still too large and they overlap between each other, so classification is not possible.

5. CONCLUSION

The first analysis intended to evaluate the quality of DTM for the Neusiedler See project. While the area is relatively flat and the DTM was calculated from fine georeferenced lidar points, which means that systematic errors are eliminated, we expected high quality DTM. The expectations were confirmed by results of local quality parameters calculation. The worst DTM accuracy occurs in the forest and village area and goes up to 4 cm.

Described method of grid point related quality parameters gives promising results and fulfills requirements for clear and understandable information on DTM quality. In future, that kind of information should be interfered to the end user together with a DTM, the better like quality layers. The most important layer is a standard deviation for each grid point, which gives information about the relative accuracy.

The conclusion of the second analysis of measured intensities is that the data itself includes very important information about the scanned surface and objects on it, but many influencing factors make it impossible to use it directly. Therefore normalization is a must. In the case of the Neusiedler See project relative normalization of the measured intensity was done on the basis of identical points. According to presumptions and simplifications we corrected measured intensities for the influence of the measured range. Relative normalization can improve the intensity image to be more velar, and homogenous, but the range of intensity values for a certain feature do not change. Therefore the classification is not successful. In the future we should research the change of intensity values, that represents certain feature. In this way the correlation between the intensity and range could be defined directly and more accurately, which would result in better corrections and finally enable (automatic) classification. For the extraction of intensities that belong to the feature, additional data would be needed, like digital ortofoto, cadastral data, terrestrial measurements.

REFERENCES

Attwenger, M., Chlaupek, A. 2006. Erstellung eines grenzüberschreitenden digitalen Geländemodells im Nationalpark Neusiedler See-Seewinkel/Fertö Hanság aus Laserscanner-Daten. Strobl, J. (ur), Blaschke, T. (ur), Griesebner, G (ur). Angewandte Geoinformatik 2006, Beiträge zum 18. AGIT-Symposium. ISBN3-87907-437-2: 16 – 23.

Attwenger, M., Chlaupek, A., Ressl, C. 2006. Berechnung des digitalen Gelände- und Oberflächenmodells Analyse des digitalen Geländemodells Orthophoto-Berechnung. Poročilo projekta. I.P.F. TU Dunaj.

Bitenc, M. (2007). Analiza podatkov in izdelkov zračnega laserskega skeniranja na projektu Neusiedler See. Diplomska naloga. Ljubljana: Fakulteta za gradbeništvo in geodezijo, Oddelek za geodezijo.

Chaupelek, A., 2006. Die Erstellung eines digitalen Geländemodells des Nationalparks Neusiedler See - Seewinkel aus flugzeuggetragenen Laserscannerdaten zur Detektion natürlicher Senken. Dišlomarbeit, Fakultät für Geowissenschaften, Geographie und Astronomie, der Universität Wien.

Hasegawa, H. 2006. Evaluations of LIDAR reflectance amplitude sensitivity towards land cover conditions. http://www.gsi.go.jp/ENGLISH/RESEARCH/BULLETIN/vol-53/53-6.pdf (8.12.2006)

Herzig, A., Horvath, D., Kraus K., Naumann K. 2002. Ein Beitrag zur Renaturierung des Nationalparks Neusiedler See-Seewinkel/Fertö-Hanság mit Hilfe von Laserscanning. Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 90. Jahrgang (2002), Heft 2/2002; 34 - 42.

Horvath, D., 2001. Ein Geländemodell aus Laser-Scanner-Daten als Grundlage eines Informationssystems für den Nationalpark Neusiedler See-Seewinkel. Diploma thesis, Institute of Photogrammetry and Remote Sensing, Vienna University of Technology.

Hug, C., Wehr, A. 1997. Detecting and identifying topographic objects in imaging laser altimeter data. IAPRS, Vol. 32, Part III–4 W2, Stuttgart, September 17-19 1997.

Kager, H. 2004. Discrepancies Between Overlapping Laser Scanning Strips- Simultaneous Fitting of Aerial Laser Scanner Strips. International Society for Photogrammetry and Remote Sensing XXth Congress. Istanbul, 07-12-2004: 07-23. http://www.ipf.tuwien.ac.at/publications/ISPRS_2004_Istanbul/Aerial_Laser_hk.pdf (8.12.2006)

Karel, W. 2005. Quality Parameters of Airborne Laser Scanner Projects: Results and Discussion. Presentation on University Course: Laser scanning - Data Acquisiton and Modeling. Institute of photogrammetry and remote sensing, TU Vienna, 6. 10.-7. 10. 2005.

Karel, W., Kraus, K. 2006. Quality parameters of digital terrain models. V: Höhle, J. (ur.). Seminar on Automated Quality Control of Digital Terrain Models. Aalborg, Denmark. EuroSDR. In press. http://www.land.aau.dk/~jh/dtm_checking/SpecialContribution.pdf (8.12.2006)

Karel, W., Pfeifer, N., Briese, C. 2006. DTM quality assessment. Talk: ISPRS Technical Commission Symposium. Vienna; 07-12-2006 - 07-14-2006. In: ISPRS Technical Commission II Symposium 2006, International Archives of the ISPRS, XXXVI/2 (2006), 1682-1750: 7 - 12.

Kraus, K., Karel, W., Briese, C. and Mandelburher, G. 2005. Local accuracy measures for digital terrain models. Photogrammetric record. In preparation.

Laserscannermessung mit zeitgleicher digitaler Bilddatenerfassung Neusiedler See. Projektbericht. March 2005. TopScan.

Lutz, E., Geist, T., Stötter, J. 2003. Investigations of airborne laser scanning signal intensity on glacial surfaces-utilizing comprehensive laser geometry modelling and orthophoto surface modelling (a case study: Svartisheibreen, Norway). In: IAPRS, 34(3/W 13). Dresden: 143 -148. http://www.isprs.org/commission3/wg3/workshop_laserscanning/papers/Lutz_ALSDD2003.pdf (9.12.2006)

Song, J.H., Han, S.H., Yu, K., Kim Y. 2002. Assessing the Possibility of Land-cover Classification Using Lidar Intensity Data. IAPRS 34, 4. Graz, 9-13 September.

Wagner, W. 2005. Physical Principles of Airborne Laser Scanning. Paper from University Course: Laser scanning - Data Acquisiton and Modeling. Institute of photogrammetry and remote sensing, TU Vienna, 6. 10.-7. 10. 2005.

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