APPLYING LASER SCANNING AS A BASIS FOR DERIVING ORIENTEERING MAPS OF VIENNA

Ditz Robert, Gartner Georg
Institute of Military Geography, Ministry of Defence, Austria
Institute of Geoinformation and Cartography, Technical University of Vienna
kdofueu.img.geo@bmlv.gv.at
georg.gartner@tuwien.ac.at

Abstract

The municipal department 41 - surveyors of the city of Vienna offers the MZK (the 'multipurpose map' of Vienna) together with a terrain model derived from aerial photogrammetry at the scale of 1:2 000 and a contour interval of 2 meters for the entire territory of Vienna as a data basis for the production of orienteering maps. The technology of Laser Scanning, already used at the municipal department 41 - surveyors, is an accurate method for deriving topographic data. In this article it is analyzed, whether laser scanning technology can be used as a basis for deriving orienteering maps. Examples will show the differences of data quality of contour lines created either by photogrammetric means or as a result of laser scanning. Further on a comparison with the end product, the orienteering map, is given.

1) INTRODUCTION

Orienteering is an increasing popular sport. More and more active participants in a lot of countries are interested in the combination of mental (orienteering) and physical (running) challenge. As a fundament of this sport specific maps have to be produced. Technologies for data acquisition and map creation are often standardized and aim for high quality products in terms of accurary and suitability for runners. The orienteering scene in Austria is highly active and competitive (also on an international level) and demands therefore for high quality maps.

In this paper a short overview of the status quo of orienteering in Austria is given. Further on a short description of the technology of laser scanning leads to the analyses of the potential of applying contour lines, derived from laser scanning, into an orienteering map creation process. This is done by desribing the basic principles and by comparing the contour lines of a photogrammetric interpretation, laser scanning data with interpolated contour lines and an exisiting orienteering map of a part of Vienna (scale 1:15000).

2) STATUS QUO OF ORIENTEERING IN AUSTRIA

In Austria 82 clubs with 2230 inscribed members are registered at the ÖFOL, the Austrian association of orienteering (as of 24th April 2005). Every year 15 Austrian championships (skiing, classic, school and mountain bike) are held, partially as national orienteering events. In 2005, 11 national classic orienteering events, 7 skiing cup events and 8 mountain bike cup events will be organised to establish the Austrian ranking lists. Beside these national events several regional and small cup events will take place.

The first orienteering maps of Austria were produced in 1964 at the scale of 1:25 000 mainly with a contour interval of 20 meters. The first specialised orienteering map was the map "Ramaseck" in Vienna with a scale of 1:16667 and a contour interval of 10 meters. Since the beginning 1052 maps (all kinds of maps, also the revised maps) have been produced (status February 2005, map archive of ÖFOL). From 1986 until 2003 orienteering maps with an area of 1070 km² have been mapped. The dispersion related to the Austrian topographic map of 1:50.000 is shown in figure 1.

Most of the orienteering maps are produced by using photogrammetric data, being offered by municipial and federal administration and by private companies. A standardized quality of maps, as demanded by the International and National Associations, is hardly achievable due to the different levels of data acquisition accurary and quality. By aiming for more standardized and accurate data the evaluation of new technologies might be useful. As far as the authors of this paper know, the method of laser scanning has not been critically analyzed in Austria in terms of the possible potential as a data acquisition technique especially for deriving orienteering maps.

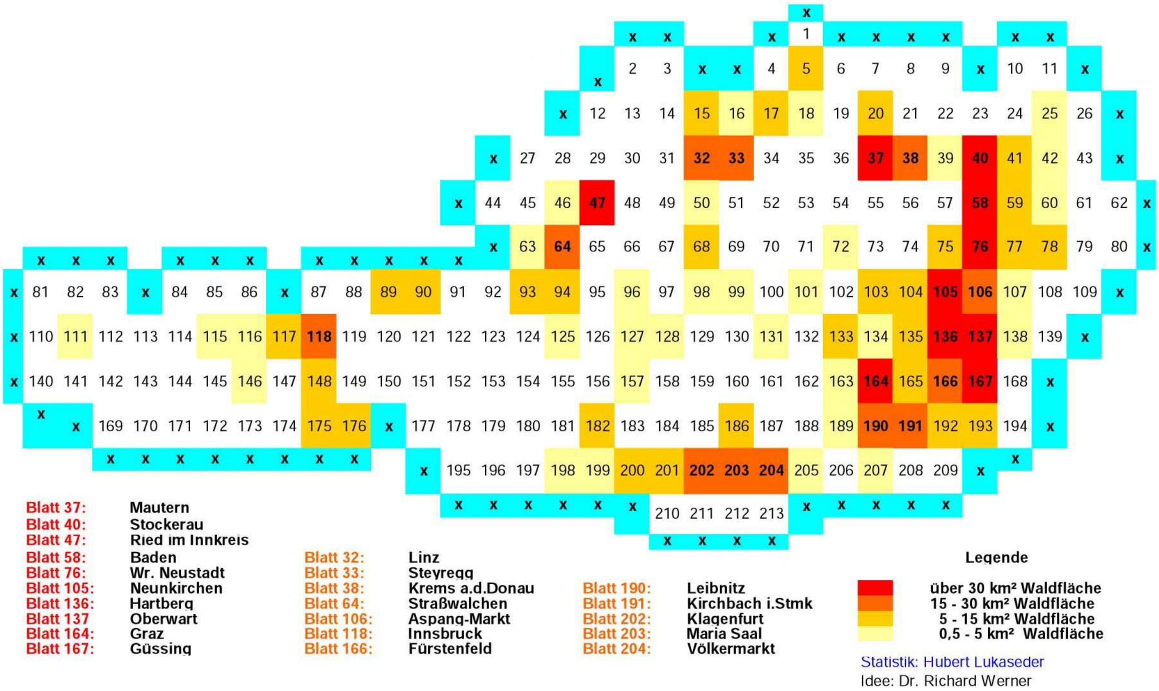

Figure 1: Dispersion of Orienteering Maps in Austria from 1986 until 2003 (Lukaseder 2004)

3) LASER SCANNING AS A NEW TECHNOLOGY FOR DATA ACQUISITION

3.1) Introduction

According to for instance Kraus (2000), Attwenger & Briese (2003) and Pfeifer (2003) laser scanning technology, both terrestrial and airborne, has encountered great technological advance during past few years. It gives the opportunity to acquire great amounts of precisely measured data in very short time. The great challenge is to deal with these huge data-sets thoroughly and produce a competent and rather automated workflow, from data capture up to the desired product. This product comprises most of the times a Digital Surface Model (DSM) of the investigated object. Once the DSM is created many follow-up products can be derived without difficulties.

3.2) Airborne Laser Scanning

Airborne laser scanning, often referred to as lidar or laser altimetry, is a remote sensing technique which measures the round-trip time of emitted laser pulses to determine the topography of the Earth's surface. While the first commercially available airborne laser scanners recorded only the time of one backscattered pulse, state-of-the-art systems measure first and last pulse; some are able to measure up to five pulses. This is because there may be several objects within the travel path of the laser pulse that generate multiple echoes. Pulse detection is then used to determine the location of these individual scatterers.

Airborne laser scanning is a rapidly growing technology which has initially been conceived for topographic mapping. Airborne laser scanners employ, with few exceptions, pulsed lasers that repetitively emit short infrared pulses towards the Earth's surface. Some of the energy is scattered back to the sensor where it is measured with an optical receiver. A timer measures the travelling time of the pulse from the laser scanner to the Earth's surface and back. Since the round-trip time is directly related to the distance of the sensor to the ground, the topography of the Earth's surface can be reconstructed. One advantage of airborne laser scanning compared to classical photography is that laser scanners are not dependent on the sun as a source of illumination. Consequently, the interpretation of laser scanner data is not hampered by shadows caused by clouds or neighbouring objects. For example, laser scanner pulses may travel unimpeded back and forth along the same path through small openings in a forest canopy, providing information about the forest floor. In contrast, optical images provide information only about the illuminated top layers of the forest canopy, while lower canopy layers and the forest floor constitute a dark background.

The development of airborne laser scanning has been largely technology driven, but advances in our understanding of the measurement process have quickly led to system improvements. The first commercially available airborne laser scanners recorded the time of one backscattered pulse. The recording of only one pulse is sufficient if there is only one target within the laser footprint. In this case the shape of the reflected pulse is “single mode” and straightforward to interpret. However, even for small laser footprints (0.2 - 2 m) there may be several objects within the travel path of the laser pulse that generate individual backscatter pulses. Therefore more advanced laser scanners have been built which are capable of recording more than one pulse. State-of-the-art commercial laser scanners typically measure first and last pulse; some are able to measure up to five pulses. Still, the problem is that it is not always clear how to interpret these measurements for different targets, particularly if the detection methods for the determination of the trigger pulses are not known. Pragmatically, one may for example assume over forested terrain that the first pulse is associated with the top of canopy and the last pulse, with some probability, with the forest floor. However, due to the 3D structure of natural and artificial objects, the form of the received pulses may be quite complex. The number and timing of the recorded trigger-pulses are therefore critically dependent on the employed detection algorithms. Consequently, it appears to be the logical next step to employ laser scanners that are able to record the full-waveform. In fact, first commercial full-waveform laser scanner systems will become available in the near future.

Another, to a certain degree oppositional trend in laser scanner scanning, is the design of laser beams with smaller and smaller beam divergence (tendency to “single mode” signals). With this sensor the number of multiple returns per emitted pulse will decrease, due to the fact that a smaller surface patch is illuminated. Since the acquired information per beam decreases, classification of the data is only possible in relation to neighbouring echoes. An interesting aspect for the future system design may eventually be the combination of narrow (only one single return with high quality range information) and wide (recording the full-waveform information) beams in order to use the advantages of both techniques (cp. Kraus (2000), Attwenger & Briese (2003) and Pfeifer (2003)).

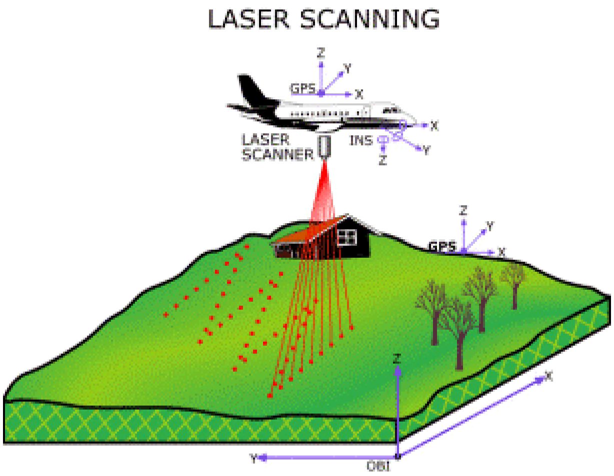

Figure 2: Principles of Airborne Laser Scanning (Vilchek 2004)

It can be stated, that Airborne Laser Scanning is a interesting technology for gathering topographic data, especially also in forested areas in a short time. As orienteering maps usually covering forested areas it seems an interesting opportunity to use laser scanning technology for this application field.

4) COMPARISON AND EVALUATION OF VARIOUS DATA SOURCES

4.1) General Considerations for Data Basis for Orienteering Maps

Kotylo (2002) specifies the possible data basis for an orienteering map with the pros and the cons as follows:

Type of data basis	Pros	cons
Orthophoto	High accuracy, many basic points and lines.	Problems with the projection on slopes, high trees (shadows) and no elevation information
Map 1:25 000	Accuracy of heights is 10 meters or better in case of elevation numbers. Some details	Insufficient accuracy in position

	can be used as basic points (parting of ways, edges of the wood)	
Map 1:10 000 or 1:5 000	A good basis for settlements and for heights.	
Photogrammetric Interpretation	A good basis for horizontal arrangement and for heights.	Expansive and not always well
Aerial Images	Cheap	Aerial Images are only accurate in the middle of the image and too many images are necessary.

Table 2: Possible Data Basis for Orienteering Maps (Kotylo 2002)

In general it can be stated, that the usage of various data basis is dependent on a specific regional or national situation. The situation is Austria can be described as especially difficult due to the fact that the basic official national topographic map series is of the scale of 1:50.000 with a contour interval of 20 meters. But, orienteering map creation demands for scales of base topographic data of at least 1:10.000. In Austria such sources are only available as a result of direct photogrammetric acquisition, except in some urban areas, where city administration offices cover their municipality area by specific maps and/or photo imagery. Also because of this specific Austrian situation, the usage of a technology like laser scanning might offer additional possibilities for data acquisition. In order to estimate the potential of laser scanning in this context, a pragmatic evaluation and comparison is necessary. In the following description an applied test is described.

4.2) Test Area and the Used Data Basis

Different data in a test area have to be identified, analysed for a potential use as a data basis for the creation of an orienteering map and finally a rating of the results have to be found. The selection of a test area is done due to the idea, that an exisiting orienteering map is available as well as data sets from photogrammetric interpretation and laser scanning.

Existing Orienteering Map:

The test area, typical for the "Vienna Wood Region" with deep trenches, is in the western part of the city of Vienna. The orienteering map "Sophienalpe", created in 1977 with a contour interval of 5 meters and "Hadersdorf", created in 1978 with a contour interval of 10 meters were prepared for the scale 1: 15 000 by members of the Viennese Club "Naturfreunde Wien" (Bonek 2005). The maps were combined to one map and revised for the first time in 1992 for a 5 days event, organized together with the club "HSV Wiener Neustadt". The scale of this map was 1:15 000 with a contour interval of 5 meters. The cartographic design and work was done manually in the classic cartographic way. The second revision of the part "Hadersdorf" was executed in 2004, accomplished with OCAD, with the possibility for a print at the scale of 1:10 000.

The used basis for the field work was the printed MZK (the 'multipurpose map' of Vienna) at the scale of 1:2 000 with contour lines and a contour interval of 2 meters. This map series, released by the municipal department 41 - surveyors, is available for the entire territory of Vienna. The contour lines are derived from a photogrammetric interpretation.

The first problem for preparing the basis for the field work was the different base height level used in Vienna differing 155 meters from the official Austrian base height level of Triest (mean Adriatic Sea level). In a first step this difference had to be corrected. Due to the contour interval an interpolation of each 10 meter contour line was necessary. Thus a potential of systematic mistakes is existing.

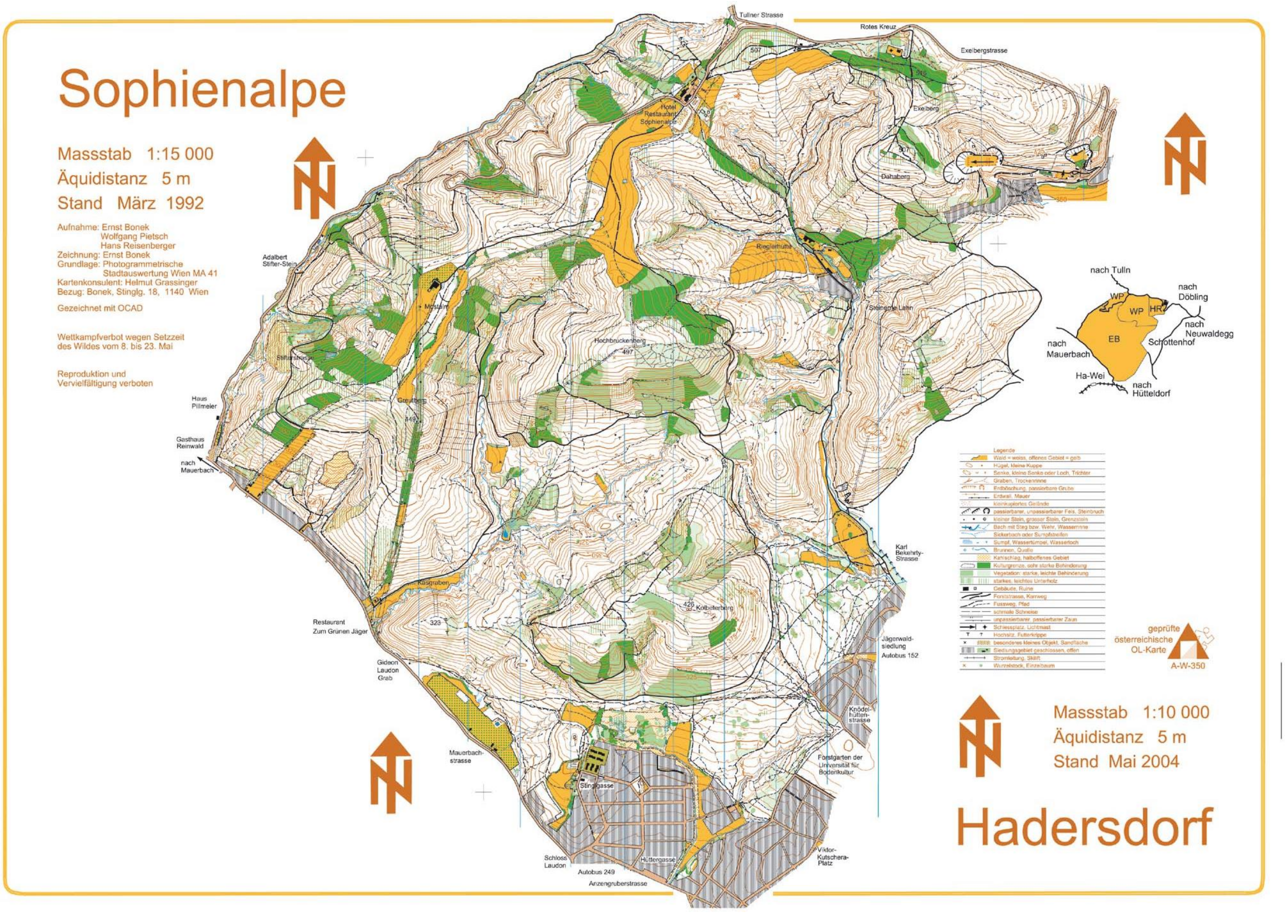

Figure 3: Orienteering Map “Sophienalpe - Hadersdorf”

Photogrammetric interpretation:

Digital data of the contour lines from a photogrammetric interpretation campaign have been available also. The parameters of this data acquisition are listed in table 1. A change of the reproduction scale since the first survey to the scale of 1:1 000 has been started in 1984 and was finally completed in 1996.

Flying Height above Ground	1700 m
Lens	21 cm
Mean Image Scale	1:7 000
Reproduction scale	1:1 000
Accuracy of Contour Lines	± 20 cm

Table 1: Parameters of the photogrammetric interpretation

Laser Scanning:

The second data basis for the comparison is the laser scanner data from the municipal department 41 surveyors from a project in the year 1996 together with the Institute of Photogrammetry and Remote Sensing, University of Technology in Vienna. The objective of this project was to derive a digital elevation model of the Vienna Woods with an accuracy of ± 25 centimetres in flat areas and an accuracy of ±1 meter in steep terrain. The parameters of this data acquisition are listed in table 2.

Used Laser	
Company	Optech Inc., Canada
Laser	ALTM 1020
Wave Length	1047 nm (near infrared)
Measuring Principle	runtime measuring
Measuring Rate	2000 Hz
Scan Rate	30 - 50 Hz
Scanning Spot	20 cm at 1000 m flying height
Flight Parameters	
Company	Topscan, Germany
Mean Flying Speed above Ground	70 m/s
Mean Flying Height above Ground	1000 m
Scanning Area	+/- 20 m
Distance between Flight Stripes	250 m
Flying Time	8 hours in 2 days
Area of Campaign	91 km²
Density of Points	about 4.5 m by 4.5 m

Table 2: Parameters of the laser scanning data

The contour lines in the parts of the forest are derived from a filtered cloud of points under consideration of photogrammetric determined break lines in the program SCOP with a contour interval of 1 meter, combined with a terrestrial surveying in the parts of settlement. These data are not representative for any laser scanning data, as they have been especially prepared. Nevertheless, it can be stated, that for the context of creating orienteering maps, the usage of break lines for modelling the surface and displaying the surface by contour lines seems to be an indispensable demand.

4.3) Comparison and Discussion

The comparison of the digital data with the orienteering map was not possible over the entire map. One reason for this fact might be a paper distortion of the original multipurpose map of Vienna, which has been transferred to both revisions. This is in fact no big problem for orienteering, because accurate positioning is not essential, important is the relation of map elements to each other, 5% difference in distance as Kotylo pointed out. The absolute accuracy in height is also of no relevance, relative differences in height between neighbouring map objects should be presented in orienteering maps as accurate as possible.

For the comparison a partial fitting of the orienteering map was therefore done. All following pairs of examples show the same part of area. The left part of the figure presents the contour lines in violet from the photogrammetric interpretation with a contour interval of 2 meters and the right part of the figure shows the contour lines derived from laser scanning data in red with a contour interval of 1 meters with break lines in grey from the situation layer of the multipurpose map of Vienna.

Comparison:

It can be seen in figure 4, that main morphological structures are represented in both presentations. On steep slopes without any further terrain features like trenches, erosion gullies or small land forms, the modelling of laser scanning data provides usable results. Only smoothing at the top of the hill and a post processing of the contour lines on the saddle is necessary.

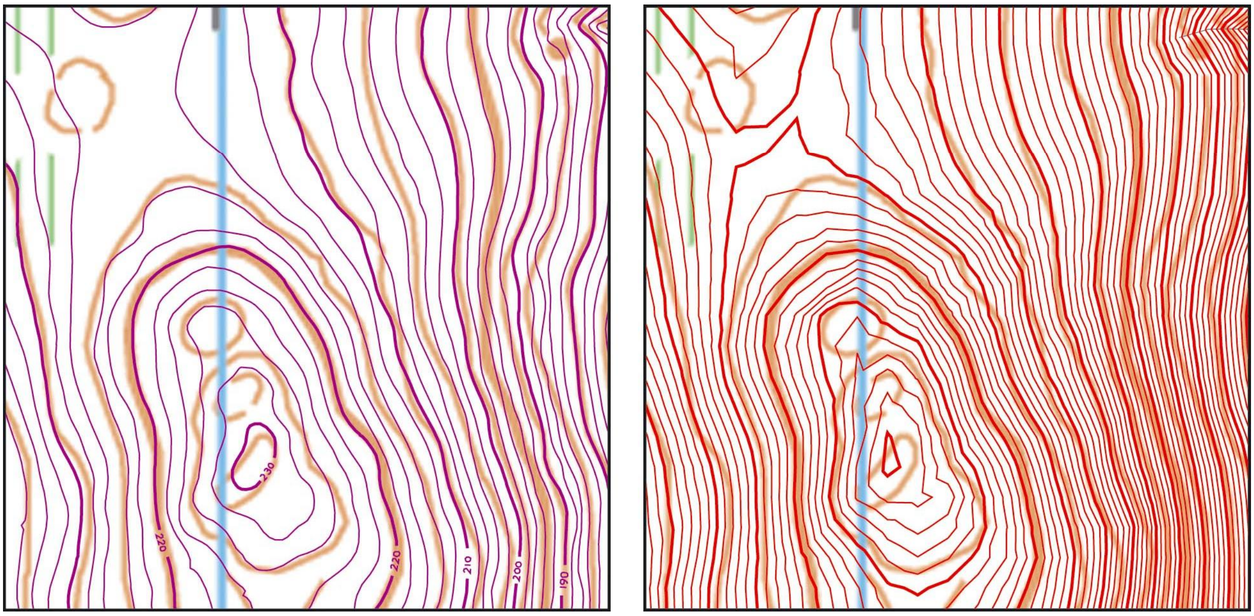

Figure 4a and 4b: Main morphological structures in steep areas

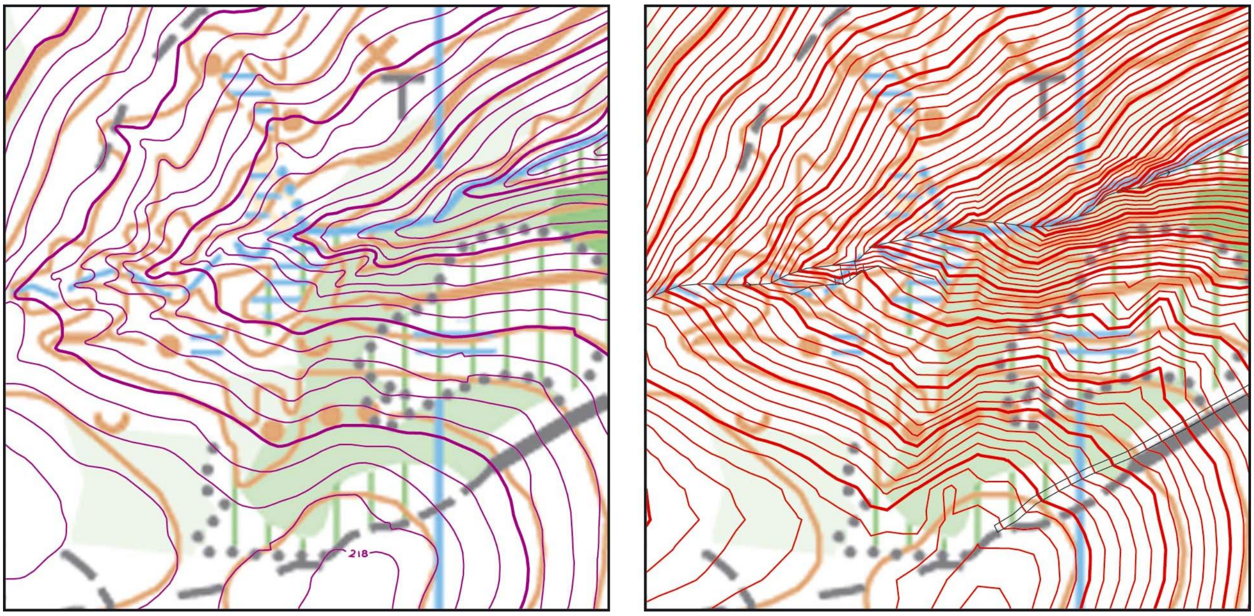

Figure 5a and 5b:

Figure 5 demonstrates the problem of contour lines, which are not specifically postprocessed (as seen in figure 5b), do represent an overall structure instead of many small structures. Compared to the traditional techniques of the geodetic method, in this example the surface is represented by far more contour lines. Thus, the details of the surface is far better represented. Even small geomorphological details are represented as shown by the visualisation. But in order to accentuate overall structures a postprocessing by adapting selected parts of contour lines would be useful (cp. the overall structure on fig. 5a and 5b).

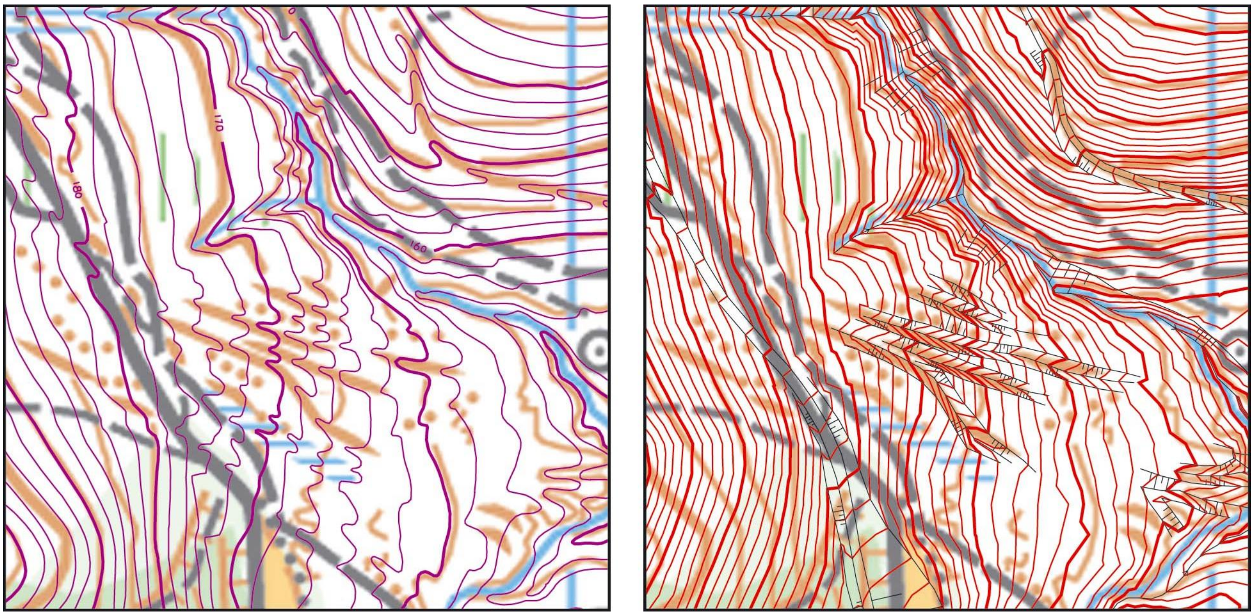

Figure 6a and 6b: Small erosion gullies supported with break lines

Figure 6 is a good example how the break lines assist for the derivation of contour lines. In all cases where no break lines are available, no small land forms are represented, as shown in the western part of figure 7b. A special not explainable phenomenon is visible in this figure. The laser scanning derived contour lines intersect the contour lines of the orienteering map at the moderate inclined slope at the south-western part of this example. The break lines of the trail ascending this slope offers an extensive error in position. On the other side the deep trenches modelled with the breaking lines are quite accurate. Small land forms like knolls and depressions or pits are not visible in the terrain representation.

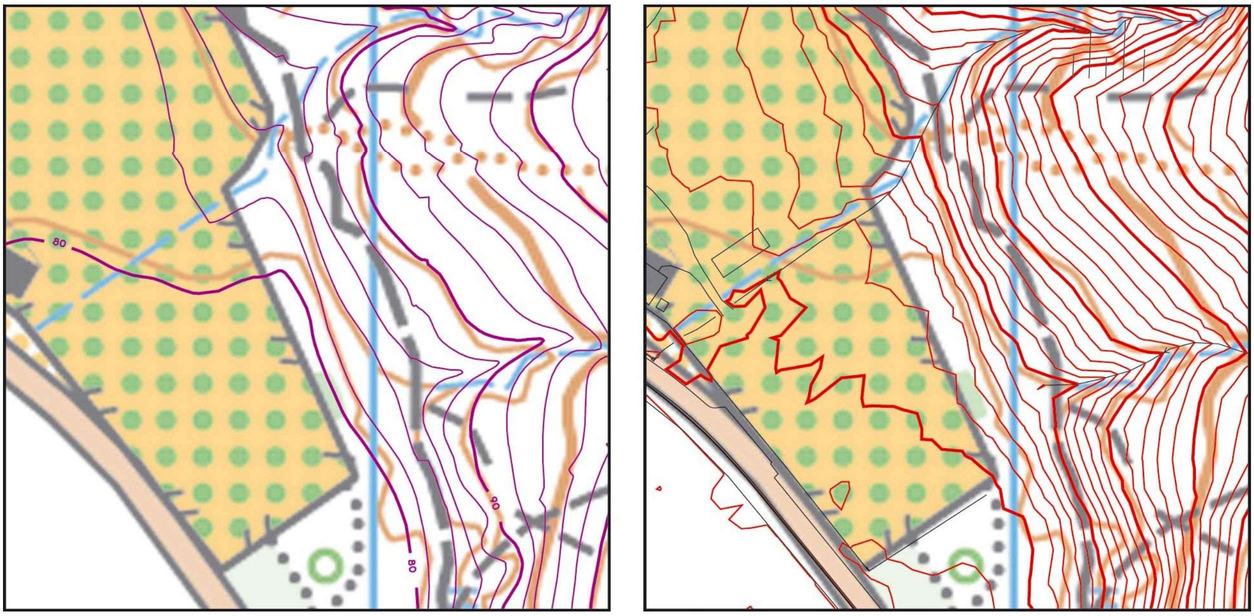

Figure 7a and 7b:

In the flat areas the laser scanning derived contour lines are not useable without postediting as shown in figure 7b. A smoothing process of the contour line running through the orchard is inevitable. The small erosion gully in the north-eastern part of this example and the two swales at the south with a trail running through are not drawn-out of the laser scanning data. Only trenches supplemented by break lines are represented in the contour lines of the right part.

Discussion:

The visualisation of the first results of airborne laser scanninng data acquisition to be used for creating orienteering maps shows the potential of this technique in this context. Therefore the next step in the data analysis has to be to check for accuracy. This can be done by comparing laser scan points with known geodetic points. During further projects the synchronous acquisition of aerial photographs is planned and, in consequence, the comparison with a DEM derived by traditional photogrammetric means.

5) CONCLUSION

In this paper aspects of using various technologies as a topographic basis for creating orienteering maps are discussed. As a result the technique of laser scanning has been introduced as a possible alternative. The analyzed results lead to further questions concerning the integration of various data acquisition techniques. It can be expected, that further improvements and availability of laser scanning technique will offer additional possibilities and increase the possibilities of creating orienteering maps. The usage of break lines seems to be indispensable for the creation of useful contour lines out of laser scanning data. The most important process during the creation of an orienteering map is furthermore the field work with the cartographic surveying of land forms and terrain features not derivable out of photogrammetric interpretation or from an analytical derivation of contour lines from laser scanning data.

REFERENCES

ATTWENGER, M. & C. BRIESE (2003): Vergleich digitaler Geländemodelle aus Photogrammetrie und Laserscanning; Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 91. Jahrgang, 4, pp. 271-280.

BONEK, E. (2005): Personal Conversation.

KRAUS, K (2000): Photogrammetrie, Band 3, Topographische Informationssysteme, Dümmler, Köln.

KOTYLO, O. (2002): Methoden und Erfahrungen beim Zeichnen von genauen OL-Karten. Script from a mapping course from 5.-7. April 2002 in Raach, Austria.
http://www.oefol.at/intern/kommissionen/karten/kartenzeichner.htm (site visited 28.March 2005)

LUKASEDER, H. (2003): http://www.oefol.at/intern/kommissionen/karten/kartenflaechen.htm (site visited 28.March 2005)

PFEIFER, N. (2003): Oberflächenmodelle aus Laserdaten; Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 91. Jahrgang (2003), 4, pp. 243- 252.

VILCHEK, L (2004): Watershed Managment.
http://www.sfwmd.gov/org/wrp/wrp_evg/projects/vegmap.html (site visited 28.March 2005)

BIOGRAPHIES

Ditz Robert:
Born in 1965 in Mödling near Vienna, Master degree in Geodesy/Cartography at the University of Technology in Vienna, 5 years working at the Institute of Cartography and Reproduction Techniques at the University of Technology as a teaching and research assistant, since 2001 at the Institute of Military Geography in Vienna.

Gartner Georg:
Georg Gartner (born 1966) is an Associate Professor at the Research Group of Cartography at the Vienna University of Technology. He holds graduate qualifications in geography and cartography from the University of Vienna and received his Ph.D. from the Vienna University of Technology and a Habilitation 2001.