CO-042

USE OF AIRBORNE LASER SCANNING DATA FOR UPDATING TOPOGRAPHIC MAPS IN HILLY AND MOUNTAIN AREAS

PETROVIC D., PODOBNIKAR T.

University of Ljubljana, LJUBLJANA, SLOVENIA

ABSTRACT

Slovenia has a crucial problem of regular updating of topographic data at different levels. The largest scale map which is regularly updated is National topographic map at the scale 1: 50,000, but without any detailed data capture in wooden areas. Larger scale topographic maps and basic topographic database were captured only partly and they have no strict updating program. On the other hand the airborne laser scanning data became one of the most promising source data for deriving different spatial data. Some methods and procedures are already efficiently used in urban environment and forestry, while use for deriving topographic features is still rare. Therefore some tests about possible use of ASL data for updating topographic data were made. As a study area part of Sava valley near the Jesenice with neighboring slopes was used. According to analyses and tests some rules which can be followed in attempt to partly automate the procedure of recognising specific features for updating topographic maps were extracted.

KEYWORDS

topographic data, airborne laser scanning, terrain features

INTRODUCTION

Topographic data create the basic parts of spatial data infrastructure. Every administration needs regularly updated spatial data for spatial management, environment monitoring, and for many other administrative tasks and purposes. Slovenia, as relatively young country, has been recognized as one of the most progressive EU countries, but status of regular updating of topographical topographic data at different levels is far from ideal (Petrovič, Duhovnik, 2009).

Nowadays topographic data are stored and available to users on topographic maps and in topographic databases. The largest scale map of Slovenia, presenting the entire territory on map sheets at the unique scale is the Slovenian National Topographic Map at the scale of 1: 25,000 (DTK 25) (Petrovič, 2006). In 1970-ies and 1980-ies Slovenia (still as a part of Yugoslavia) got 1: 25,000 topographic map as a version of military map. It was made using aero photogrammetric procedures and detailed field checking and is therefore very precise. The map was last updated in 1985 and 1986. After winning the independence, the 198 sheets of the map were published from 1994 to 1998, as a remake of former Yugoslav's military topographic map. Due to limited financial resources unfortunately the design modifications had the priority over the updating of content. Thus the degree of updating was mostly limited to only the inclusion of new connecting roads and railroad tracks, larger groups of new objects or larger individual objects, and the inclusion of new water-storage reservoirs. The marginal content with the legend, the mathematical elements of the map, explanations and colophon were indeed completely re-designed. DTK 25 boasts an extremely accurate height representation of the terrain, high legibility with high density of displayed information and good positional accuracy of all the displayed objects. The map was very popular and widely used for spatial planning, orientation and navigation on the terrain (boy scouts, mountaineering and marathon orienteering...) and is still used nowadays, although the content is out-of-date. Some segments of state administration (especially military) would be interested in updating it, but according to budget possibilities the Mapping and Surveying Authority decided that at the moment the largest scale map which is regularly updated is National topographic map at scale 1: 50,000, but again without any detailed data capture in wooded areas. The figure 1 shows an insert of DTK 25.

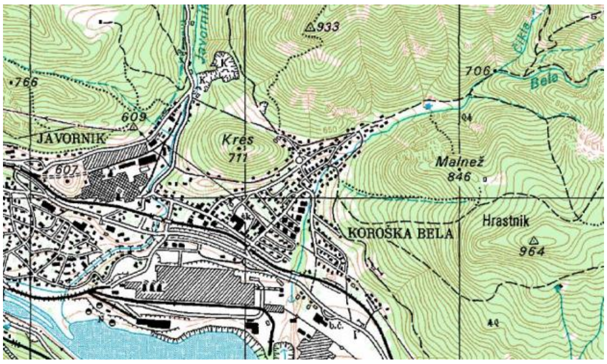

Figure 1: Slovenian national topographic maps: insert of DTK 25.

In the late 1990s the project of establishing a basic national topographic database (DTK 5) started. The essential purpose of DTK 5 was the linking of the existing topographic records and the minimal addition capture from the cyclic aerial survey (CAS) images. In the period from 2002 to 2011, about 2000 3 km × 2.25 km sheets (out of 3258 DTK 5 sheets which cover the entire territory of Slovenia) were captured (figure 2). The created sheets cover all the bigger settlements and it can be estimated that the DTK 5 encompasses no less than 80 per cent of the population. But, the capture of DTK 5 for the rest of country territory was stopped and even already captured data have not been updated in the last years.

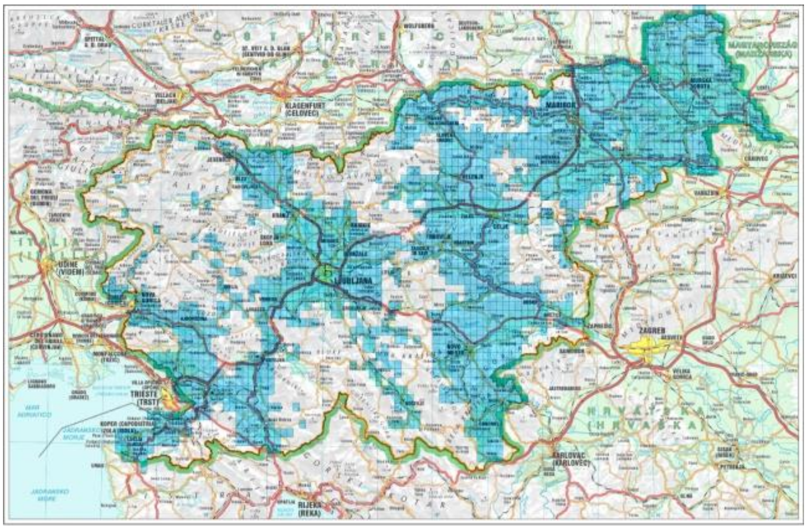

Figure 2: Territory of Slovenia, areas where basic topographic database DTK 5 exists.

In the last decade, some ideas were promoted to assure regular updating of topographical data, like official collecting of data from companies responsible for public infrastructure or attempt to updating official topographic data by users (Petrovič and Kovačič, 2008). None of them brought any significant result.

AIRBORNE LASER SCANNING (ALS)

The technology of laser scanning has importantly affected the principles of spatial acquisition of topographic and other physical data about the environment (Shan and Toth, 2009, Kraus 2007). Frequently the synonym LiDAR survey or shortly LiDAR is used. The very important advantage of LiDAR capturing is its speed; it allows capturing large area in a short period with high density (figure 3 left). The main results of airborne LiDAR survey are clouds of georeferenced points containing data on the reflection order and the intensity of the returned pulse (figure 3 right). The airborne laser scanning data therefore seem to be a promising source data for deriving different topographic data and therefore for quick, non-expensive regular updating of topographical maps and databases.

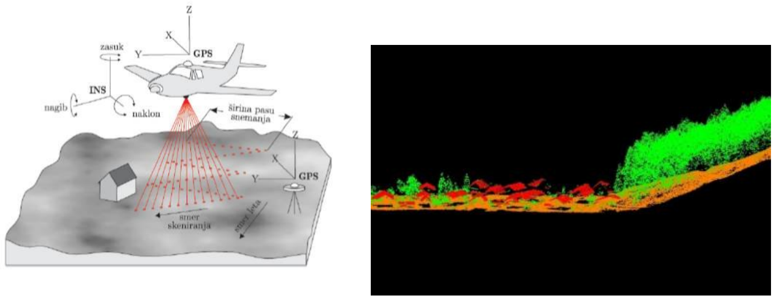

Figure 3: Principle of LiDAR capturing and classified point cloud as a result of LiDAR

To collect and classify topographic contents from the LiDAR point cloud, the recognition of individual objects and phenomena and the definition of the edges between them (i.e. edges defined by buildings, roads, etc.) are required. The success of recognition depends among others also on the LiDAR point density (Triglav Čekada et all, 2010). Recognition of objects, phenomena and edges is very attractive and intensive research topic. There are already some results in automated deriving data from ALS: edge detection and building extraction mostly in urban environment; or forest type, density, tree-height in forestry. But for the most nature made ones, small water objects, relief features, etc. such automated methods are not performed yet. For those features at the moment manual recognition of objects in different derived presentations (eg. hillshading) is still the most efficient method.

LINEAR OBJECT DETECTION AND EXTRACTION

In our case study we focused on the recognition of linear topographic objects. The main goal was to estimate the possibilities to automate the extraction of roads, paths, water streams, ridges and ditches. Our input was digital elevation model (DEM) with 0.5 m resolution derived from LiDAR data. Vegetation and buildings were a-priori removed from the data. The area 2 km x 1.7 km of the study was a combination of rough and flat relief. Figure 4 shows the study area in Sava valley near the Jesenice with neighboring slopes on the northern side of the valley. Different edge detection tolls, filters and image processing tools were tested in order to get the best possible output. Results were evaluated visually by comparing them to ortophoto and topographic maps at the scale 1: 25,000. Two different workflows were used, one for deriving water streams, ridges and ditches and another one for extraction of roads and paths.

Figure 4: The ortophoto image of the study area.

THE WATER STREAMS, RIDGES AND DITCHES

Water streams, ridges and ditches are natural objects and are directly depended on relief characteristics. The tools for hydrological analysis were used for derivation of these features. Slope direction using Multiple Flow Detection model (MFD) and flow accumulation were computed for each cell of the raster. In the MFD model flow accumulation arises for every neighbor cell which has a lower elevation than the center cell in 3x3 window. The cells in the ditches were extracted by setting the threshold of flow accumulation to 8,000. Results were converted into vector data.

For extraction of the ridges we firstly inverted DEM and then used the same procedure as described above. The threshold was set to 60,000 this time.

Results of extraction procedures in the figure 5 are covered over the standard analytical shading of DEM; light direction is set at azimuth 315° and elevation angle of 45°.

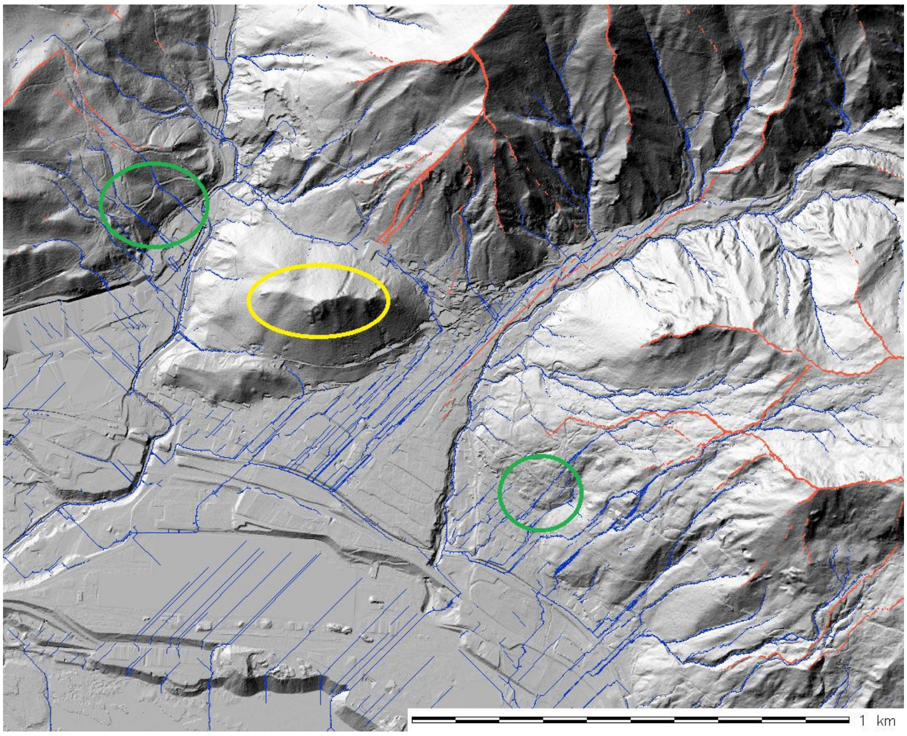

Figure 5: The results of ridges (red) and ditches (blue) extraction.

The results shown in the figure 5 are satisfactory in the hilly area, on the slopes. Most of the significant ditches were detected correctly and lines are nicely connected. Problems only occurred at the junctions of paths and ditches (marked with green in the figure 5). Since at these areas ditches' cells have the same elevation as their neighbors on the paths slope direction and consequently flow accumulation could not be determined correctly. The same reason caused obviously wrong straight lines in the flat area. Another reason for mistakes in flat area is the algorithm itself. It is more sensitive to errors (outliers) in DEM, which are likely to appear when LiDAR data are the source for DEM generation (Hohle, 2009).

The ridges were well determined. The only irregularity that appeared was undetected ridge of smaller hill, marked with a yellow color in the figure 5. The anomaly we could not explained occurred in the results of flow accumulation algorithm applied on inverted DEM which determined low values in the middle of the hill.

Above described workflow could be well used in hilly, steep areas, while in flat areas the results need some manual corrections. Figure 6 shows manually cleaned results of ditches and ridges extraction. We can compare position of water streams at the topographic map to extracted ones. Two main streams fit nicely, while deviations of lateral water streams are bigger. Whether water stream is present in the ditch have to be determinate from another data source. Aero photography could not provide all necessary information since area is covered with dense vegetation. If point cloud of LiDAR data was available, analysis of intensity of returned signal could be used for that purpose.

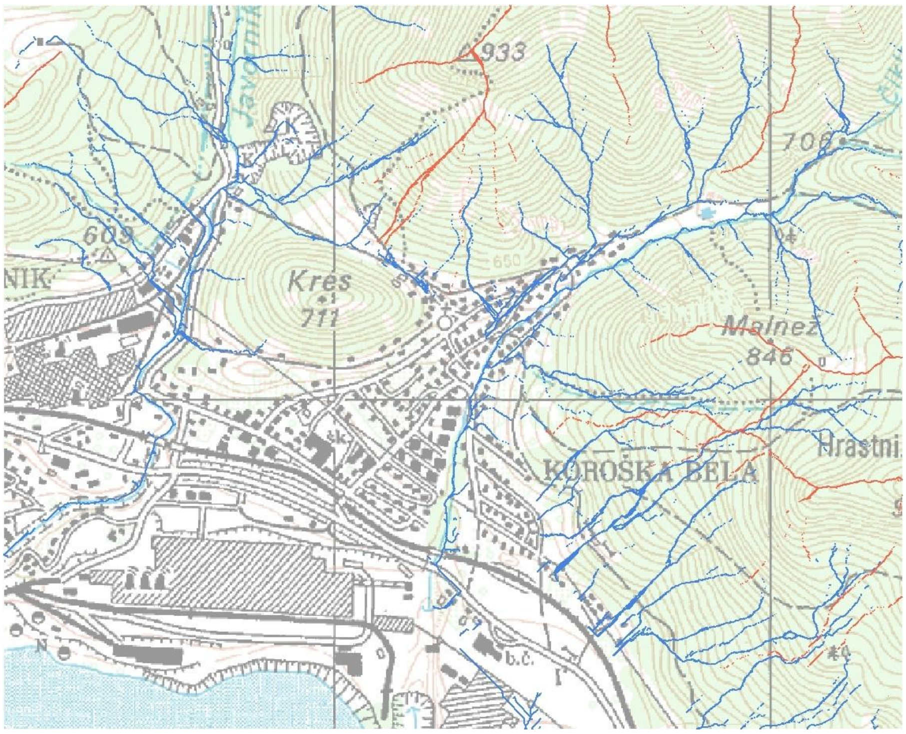

Figure 6: Manually corrected results of ditches and ridges extraction.

THE ROADS AND THE PATHS

Roads and paths in the slopes can be detected as flat linear features within the slope. Therefore we focused on slope change detection in terrain model. Firstly we generated maps of a slope, aspect, curvature and partial derivatives from the original LiDAR DEM. Since we attempted to use the image processing tools we visually estimated the suitability of each map for roads and paths extraction. The features were recognizable at the image representing a slope, while from all other images it was difficult to distinguish any pattern. Analytically hill shaded image of DEM where elevation angle was set to 90° turned out to be the most promising image for further analysis. We improved edge visibility by transformation of the histogram and by enlarging the contrast. Then different edge detection algorithms with different parameters settings were applied and analyzed. The best results were obtained using the canny method. Parameters were set to 0.2 for low threshold and 0.7 for high threshold. Additionally, the Wiener filter was performed for removing short edges which were also detected. Results of the workflow are shown in the figure 7.

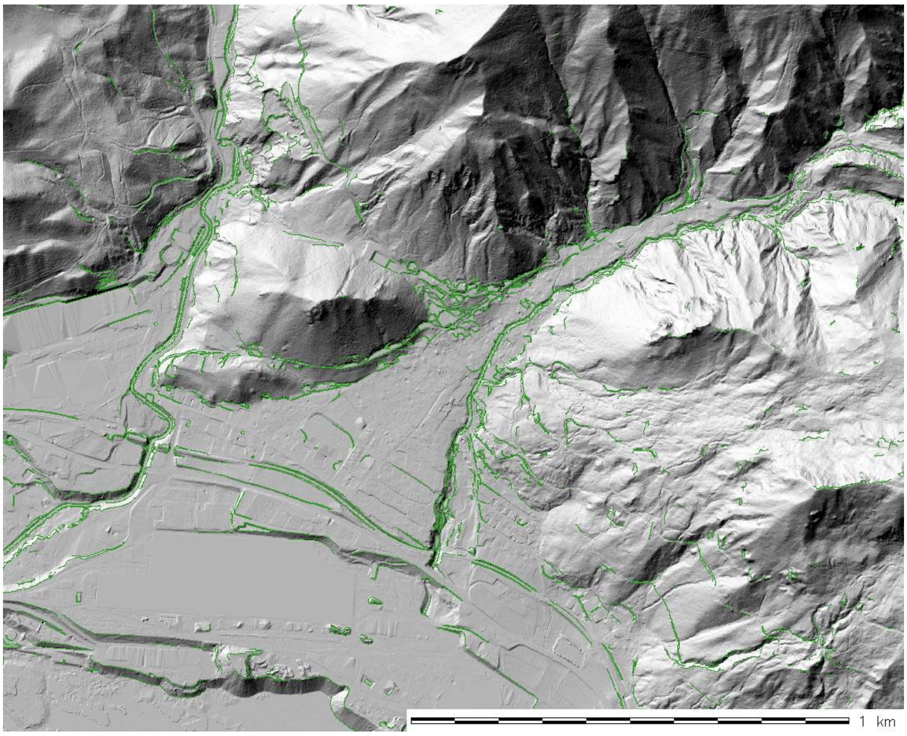

Figure 7: The results of road and paths extraction.

The results of roads and paths detection are significantly poorer than results of ridges and ditches detection. Lines are not connected, many paths and also major roads were detected only partially or were not detected at all, as can be clearly seen in the figure 8. However basic shape and pattern of road and path network can be recognized. Segments of roads and paths with clearly defined edges, i.e. those that have a significantly different slope comparing to its surrounding were detected correctly. Those segments could be used to improve positional accuracy of paths in hilly areas.

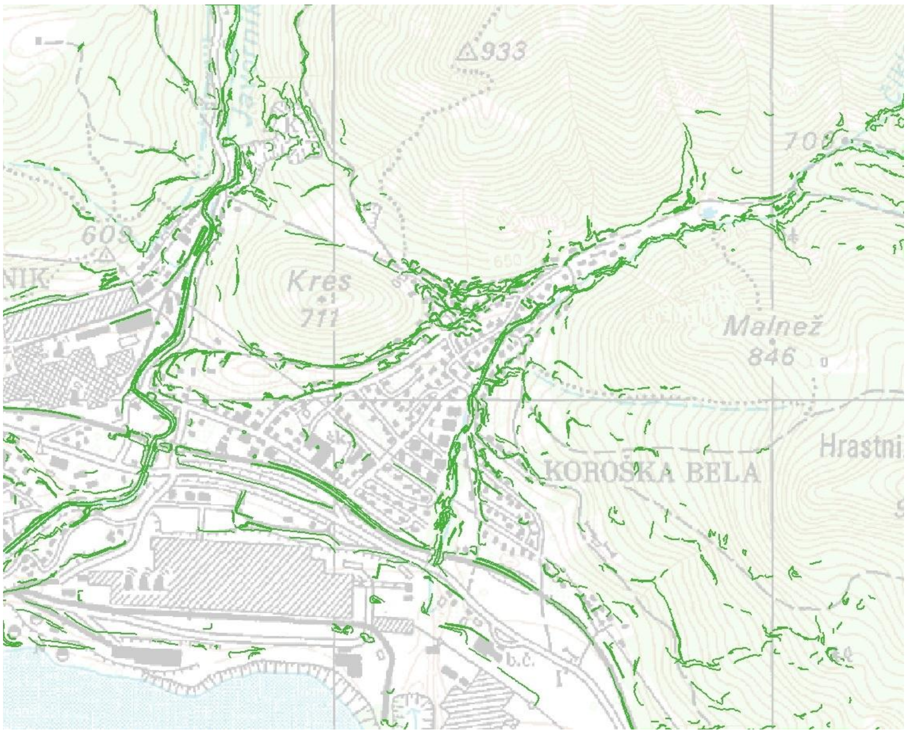

Figure 8: Manually corrected results of roads and paths extraction.

This workflow should definitely be improved in the future in order to get better results automatically. Splitting area according to its geomorphologic features and treating each class with adopted parameters could improve results. For derivation of more precise topological details LiDAR point cloud should be used directly. Roads have already been successfully detected using intensity of returned laser signal which is homogenous for surface covered by asphalt (Hu et al., 2004).

CONCLUSION

In the presented case study two different workflows for detection and extraction of linear features from LiDAR data were introduced. Instead of using point cloud data as a source we decided to take DEM derived from LiDAR data which contains much less information. The advantage of this approach is faster processing and ability to use hydrology tools and image processing tools. The quality of DEM is of crucial importance in that case, since even small errors in DEM can strongly influence results. The suggested workflow for ridges and ditches extraction gave promising results, especially in hilly areas, while the procedure for roads and paths extraction needs improvements to be applicable for extraction of paths in hilly areas. The roads and paths in flat areas do not differ significantly in elevation to its surrounding and should therefore be detected from the point cloud directly. Some terrain features look too similar in LiDAR data and sometimes even abandoned, overgrowth terrain object cannot be distinguished from the regular used ones (eg. tracks in forests). Therefore it seems to be necessary to perform some field checking too. But with following tests we would try to recognise specific appearance of as many topographic features as possible, also on other areas, different form the test one. Finally we would try to automate recognition and feature deriving procedures as much as possible.

The main goal of entire wider project is to create the procedure for capturing all necessary data for establishing and updating Slovenian topographic maps and databases. Presented analyses were only the triggering tasks that gave us basic impressions about the possibility of capturing linear topographic features from LiDAR data. In general it was obvious, that according to the others so far used mass capturing source datasets (eg. orthophoto) much more features can be derived. Especially in the areas covered with vegetation where objects are difficult or impossible to be recognized from aero photos, those procedures shall significantly reduce the cost of topographic data capturing.

REFERENCES

1. Hohle, J. & M. Hohle (2009). Accuracy assessment of digital elevation models by means of robust statistical methods. Isprs Journal of Photogrammetry and Remote Sensing, 398-406.

2. Hu, X., Tao,C.V., Hu, Y., 2004. Automatic extraction from dense urban area by integrated processing of high resolution imagery and lidar data. http://www.cartesia.org/geodoc/isprs2004/comm3/papers/288.pdf (Februar 2011)

3. Kraus, K. 2007. Photogrammetry: Geometry from Images and Laser Scans, 2nd edition. Walter de Gruyter.

4. Petrovič, D. 2006, Establishment of a Cartographical-Topographical System in Slovenia since 1990. Kartographie als Kommunikationsmedium, (Wiener Schriften zur Geographie und Kartographie, Bd. 17). Wien: Institut für Geographie und Regionalforschung der Universität Wien.

5. Petrovič, D., Duhovnik, M. 2009. Cartography in Slovenia. In: Gartner, G. (ed.), Ortag, F. (ed.). Proceedings : ICA symposium on cartography for Central and Eastern Europe, Vienna 16-17 February 2009. pg. 276-287.

6. Petrovič, D., Kovačič, B. 2008. Web Application for Topographic Maps Changes Acquisition. Proceedings of 6th Mountain Cartography Workshop, Lenk, Switzerland.

7. Shan, J., Toth, C.K. 2009. Topographic Laser Ranging and Scanning. Taylor & Francis Group.

8. Triglav Čekada, M., Crosilla, F., Kosmatin Fras, M., 2010. Theoretical Lidar Point Density for Topographic Mapping in the Largest Scales. Geodetski vestnik, 54 (3), 213-221.