"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.202
DOI: https://doi.org/10.3846/enviro.2017.202

Accuracy Assessment of Mobile Laser Scanning Elevation Data in Different Vegetation Areas

Kaupo Kokamägi[1], Natalja Liba[2], Kristo Must[3], Martin Sirk[4]

[1,2,4]Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Tartu, Estonia
[1,3]REIB OÜ, Tartu, Estonia
E-mails: [1]kaupo.kokamagi@student.emu.ee; [2]natalja.liba@emu.ee (corresponding author); [3]kristo.must@reib.ee; [4]martin.sirk@emu.ee

Abstract. Due to the overall development of technology, laser scanning has reached a new level. During the last decade, all the different technologies necessary for mobile laser scanning, have been developed. Due to the fact that mobile laser scanning brings the need to process very large amounts of data, development of computers and software is also very important. The aim of current research was to assess the accuracy of mobile laser scanning elevation data in different vegetation areas and to explore if mobile laser scanning could be used as an alternative to aerial laser scanning. This article only covers the data collecting, processing and accuracy assessment aspects of the research. Data used in current study was collected in summer of 2015, during mobile laser scanning of Põltsamaa-Kärevere section of E263 route (Tallinn-Tartu-Võru-Luhamaa). Three smaller, differently vegetated, sections were picked from the large project to study the accuracy of elevation data. For accuracy assessment, the mobile laser scanning elevation data was compared to the checkpoints measured with GNSS (Global Navigation Satellite Systems) device. Ground profiles were drawn based on mobile laser scanning data. For objective assessment, accuracy of mobile laser scanning elevation data was compared to accuracy of ground profile elevation data and aerial laser scanning elevation data. The study found that the RMSE (Root Mean Square Error) in the I section, which was a field vegetated with 1 metre high crop, was 0,98 metres. RMSE in the II section, which was a pasture with low and sparse vegetation, was 0,23 metres. RMSE in the III section, which contained a bushy ditch and a field behind it, was 0,61 metres. Results show that the accuracy of mobile laser scanning elevation data depends substantially on the density of vegetation in scanned areas and that drawing ground profiles reduced the RMSE of mobile laser scanning elevation data. Results show that the accuracy of mobile laser scanning elevation data depends substantially on the density of vegetation in scanned areas. On this basis it can be concluded, that the most reasonable time to conduct mobile laser scanning would be during a season, when vegetation is the sparsest. It can also be concluded that drawing ground profiles makes mobile laser scanning data more accurate.

Keywords: laser scanning, mobile laser scanning, accuracy of elevation data.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

Due to overall development of technology, laser scanning has reached a new level. In addition to that, hardware and software needed to process the large amounts of collected data has also been developing fast.

During laser scanning 3D coordinates are assigned to each scanned point. As a result, a point cloud is formed. After that, the point cloud can be processed as required (Toompuu, Alanurm 2013).

Laser scanning divides into aerial and terrestrial laser scanning. Aerial laser scanning means the scanning device is airborne and terrestrial laser scanning means the scanner is working on or near the ground.

Terrestrial laser scanning can also be divided into two categories: static and kinematic or mobile laser scanning (Vosselmann, Maas 2010).

In the static mode the scanner is fixed in one position during the whole scan. Due to the fact that the scanner is fixed in a stable position, the point clouds have a good quality. Each point cloud refers to the respective station coordinate system and it is necessary to register and georeference the point clouds from different positions. This processing is usually very time-consuming (Vosselmann, Maas 2010).

In the case of mobile laser scanning the scanner is attached to a vehicle, which moves on the ground or water or underground. Attaching the scanner on a vehicle makes the process more efficient because there is no need to set up the scanner in every new position. There is two different modes of mobile laser scanning: kinematic mode and the so-called stop-and-go mode (Vosselmann, Maas 2010).

The stop-and-go mode is a link between the static and kinematic scanning. Here the scanning takes place when the vehicle is not moving and when one position is scanned, the vehicle moves to the next scanning position where the next scan takes place (Vosselmann, Maas 2010).

In the kinematic mode the scanner is collecting data during the movement and in this mode it is required that the movement would be as homogeneous as possible. The speed of the vehicle depends on the required accuracy and the type of scanner. In this mode it is important that the vehicle also has a GNSS (Global Navigation Satellite Systems) receiver and a IMU (Inertial Measurement Unit) on board in order to link all the collected data in a unique spatial reference system. In addition, cameras are installed on the vehicle to simplify further processing of the point clouds (Vosselmann, Maas 2010).

Mobile laser scanning is mostly used when mapping long objects like roads, streets, railroads and rivers. Collected data could be used in common surveying work or for example creating 3D models.

Vehicular-based systems using laser scanners that operate on commercial basis have been introduced during the last ten years. This kind of systems are now used routinely by surveying companies. Mobile laser scanning will possibly become a commonly available service in the more advanced countries (Shan, Toth 2009).

Due to the fact that the use of mobile laser scanning for commercial purposes has increased, its accuracy and efficiency have been researched during the last decade. One interesting research was done as collaboration of University of Turku, Finnish Geodetic Institute and Helsinki University of Technology. During the research, data was collected with a boat-based mobile mapping system and a static laser scanner. The object was the Pulmankijoki River on the border of Finland and Norway. Data was collected in the summer of 2008 (Alho *et al.* 2009).

Similar research has been done elsewhere as well.

Mobile laser scanning is not used very widely in Estonia, but still there are a few companies that have the necessary equipment or have been part of some mobile mapping projects. For example one large project that involved mobile mapping was creating the 3D model of Tallinn Old Town (Kargaja 2011; Tallinn 2012).

In the summer of 2015 two mobile mapping projects were conducted in southern Estonia. These projects included mobile laser scanning of Põltsamaa-Kärevere section of route E263 and Soohara-Karisilla section of Põlva-Karisilla road. Both included the road adjacent areas. Authors of this article also took part in these two projects.

Materials and methods

The result of mobile laser scanning of the Põltsamaa-Kärevere section of route E263 was the object of this research (Fig. 1). The project was carried out on the order of Estonian Road Administration. The project was accomplished by an Estonian surveying company OÜ REIB in collaboration with Lithuanian partners, who provided the mobile scanning system and the operating crew. Road section from Põltsamaa to Kärevere was scanned as well as the road adjacent areas.

The aim of current research was to assess the accuracy of mobile laser scanning elevation data in different vegetation areas and to explore if mobile laser scanning could be used as an alternative to aerial laser scanning (Kokamägi 2016).

Fig. 1. The location of the scanned section of route E263 in Estonia (Web mapping service of Estonian Land Board)

Data collection consisted of four stages, which divide into different sections of their own. These stages were (Kokamägi 2016):

– Preparations,
– Collecting scanning data,
– Data processing,
– Additional surveys.

Preparations were marking and measuring the control points on road surface, Trimble R8 GNSS devices were used for measuring. Marking and measuring was done early in the morning, so it wouldn't disturb the traffic too much (Kokamägi 2016).

Collecting scanning data lasted about two hours. The scanning was carried out on 30th of June 2015. About 40 km of road was scanned in that time. Mobile laser scanning system StreetMapper 360 (Fig. 2) was used for this project (Kokamägi 2016).

This system has two Riegl VQ250 laser scanners. During the scanning two Ashtech XII GNSS receivers were set up on geodetic reference network points in each end of the road section and data was collected during the whole scan (Kokamägi 2016).

Fig. 2. Mobile laser scanning system StreetMapper 360

Density of the point cloud is in correlation with the speed of the vehicle. If the speed is higher, the density will be lower (Table 1).

Table 1. Average point density of VQ250 laser scanners used for scanning the Põltsamaa-Kärevere section (StreetMapper 360 Specifications)

Average point density per 1 scanner (points per square metre, 5 metres from scanner)					
Speed (km/h)	25	30	60	80	100
Point density (pt/m²)	1375	860	573	430	344

To initialize and calibrate the IMU and GNSS devices for mobile laser scanning, it was necessary to drive through the road section back and forth once. Once the system was calibrated and initialized the scanning could start. During the scan the vehicle drove at about 80 km/h through the road section back and forth. At that speed the point cloud density, 5 metres from scanner, was about 430 points per square kilometre. After the scan the calibration and initializing operations were repeated (Kokamägi 2016).

During *data processing*, the point clouds were classified and registered according to the control points. During classification points measured on the ground and vegetation were distinguished from each other and were later represented in drawing software with brown and green colors. For registering the point clouds, the coordinates of the control points and GNSS data collected during the scan were used. After that The point cloud was divided into smaller sections to make the further processing smoother (Kokamägi 2016).

After that ground profiles were drawn after every 25 metres. This was done for drawing the ground elevation model. Then objects like asphalt edges, traffic sign etc. were drawn. Panoramic images, that were taken during the whole scan, were used during drawing (Kokamägi 2016).

Additional surveys took place parallel to data processing. Spots, where there was not enough information in the point cloud, were surveyed with GNSS devices and total stations. These spots were mostly ditches and rivers crossing the road (Kokamägi 2016).

Accuracy assessment of elevation data

For accuracy assessment, the mobile laser scanning elevation data was compared to the checkpoints measured with GNSS device. For objective assessment, accuracy of mobile laser scanning elevation data was compared to accuracy of ground profile elevation data and aerial laser scanning elevation data. The aerial laser scanning took place in April 2014 and was conducted by Estonian Land Board (Kokamägi 2016).

In current study, only the previously registered and classified mobile scanning data was used (Kokamägi 2016).

Three smaller, differently vegetated, sections were picked from the large project to study the accuracy of elevation data.

The characterization of the three chosen sections (Kokamägi 2016):

I section was a field vegetated with 1 metre high crop. 73 checkpoints were measured.

II section was a pasture with low and sparse vegetation. 50 checkpoints were measured.

III section contained a bushy ditch and a field behind it. 97 checkpoints were measured.

The location of these sections along route E263 is shown on Fig. 3.

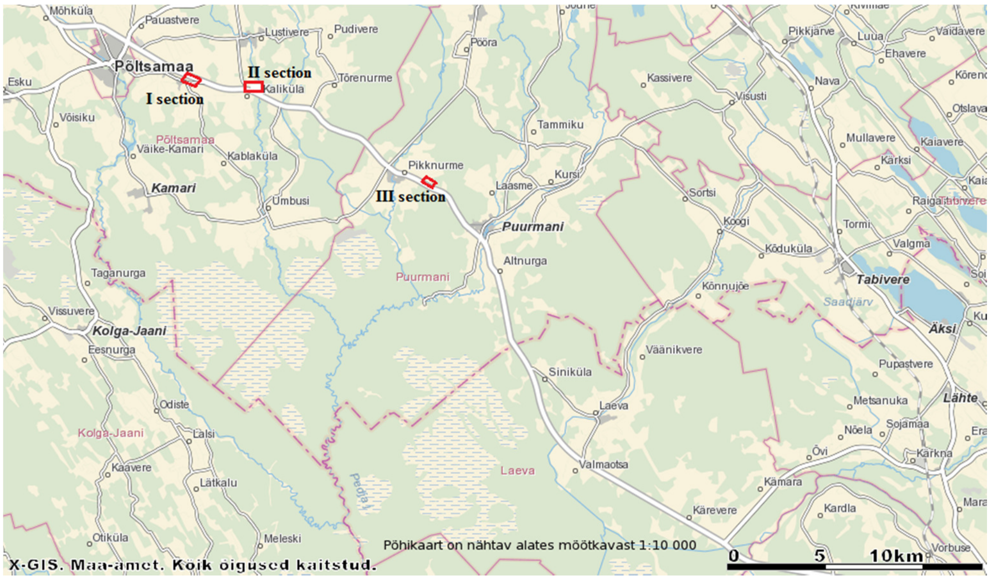

Fig. 3. The location of the researched sections I–III along the scanned Põltsamaa Kärevere section of route E263 (Web mapping service of Estonian Land Board 2016)

In each section GNSS survey was conducted after mobile laser scanning and the results of the survey were considered accurate for the research. Estonian University of Life Sciences' GNSS device Trimble R4-3 was used for this survey. Surveying of the checkpoints took place on 26th of November 2015. In every section, the points were measured in rows parallel to route E263, each row further from the road then the last. First row was 3 to 5 metres from the edge of asphalt and the rows were 5 to 10 metres apart from each other. In the I and the II section there were 3 rows and in the III section there was 6 rows, because in the III section, there were additional rows measured in the bottom of the ditch and top of the banks. The position of the checkpoints in I section is shown in Fig. 4 and the vegetation of the section during the scan is shown in Fig. 5 (Kokamägi 2016).

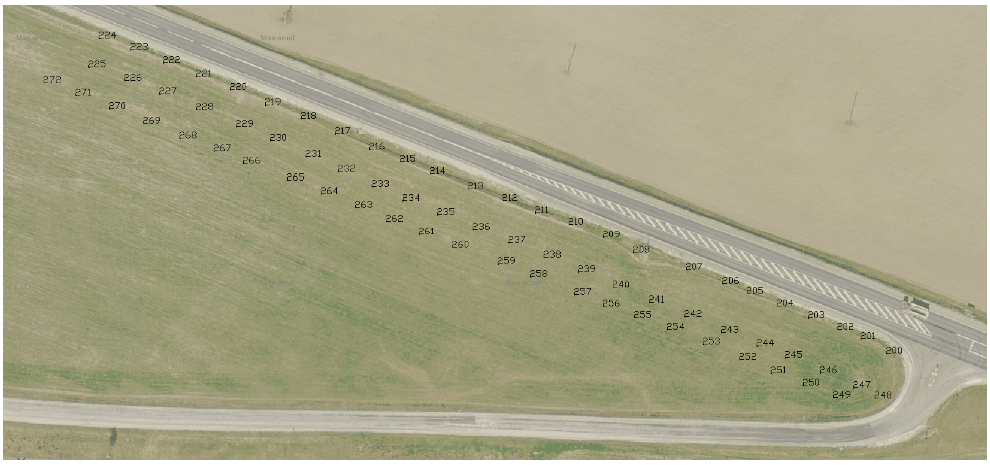

Fig. 4. The layout of checkpoints measured with a GNSS device on section I

Fig. 5. I section photographed from the mobile scanning system during the scan

As mentioned, checkpoints measured with GNSS device were considered accurate for the research. For objective analysis the elevation data of the checkpoints was compared to (Kokamägi 2016):

– Mobile laser scanning elevation data.
– Elevation data of the ground profiles based on mobile laser scanning data.
– Aerial laser scanning elevation data.

The measuring took place in three sections. RMSE (Root Mean Square Error) of every section measured with different methods were compared (Kokamägi 2016).

Gaussian RMSE formula was used for assessment of the accuracy of elevation data (Formula 1):

$$m = \pm\sqrt{\frac{[\Delta^2]}{n}}, \qquad (1)\ \text{(Randjärv 1997)}$$

where Δ is the difference between arithmetic means of the elevation data of GNSS checkpoints and elevation data measured with other methods and n is the count of measured points.

To assess the accuracy of RMSE itself, RMSE of the result was found with the following formula (formula 2):

$$m_m = \pm\frac{m}{\sqrt{2n-1}}. \qquad (2)\ \text{(Randjärv 1997)}$$

Results and conclusions

The study found that the RMSE in the I section, which was a field vegetated with 1 metre high crop, was 0,98 metres. RMSE in the II section, which was a pasture with low and sparse vegetation, was 0,23 metres. RMSE in the III section, which contained a bushy ditch and a field behind it, was 0,61 metres. The RMSE of ground profile elevation data in I, II and III section were respectively 0,69, 0,27 and 0,54 metres. The RMSE of aerial laser scanning elevation data in I, II and III section were respectively 0,05, 0,23 and 0,26 metres. It was found that RMSE of raw mobile laser scanning data was the largest and RMSE of aerial laser scanning data was the smallest in every section (Fig. 6) (Kokamägi 2016).

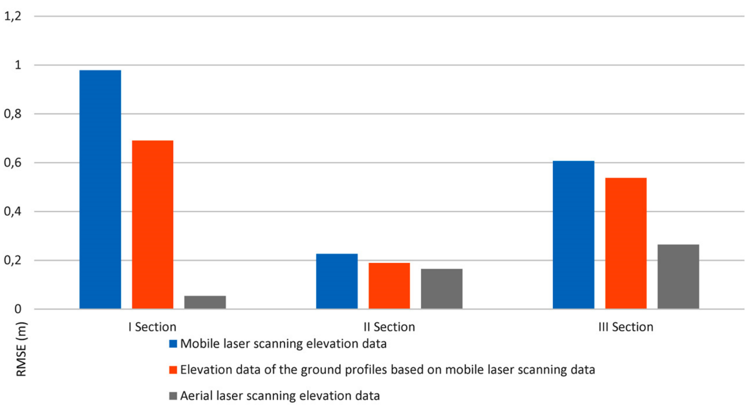

Fig. 6. Comparison of elevation data RMSE's using different measuring methods in sections I, II and III

The RMSE's of the elevation data of three sections put together were 0,70 metres for mobile laser scanning, 0,53 metres for profiles based on mobile laser scanning and 0,2 metres for aerial laser scanning. The comparison of the mean accuracy of three sections put together is shown on Fig. 7 (Kokamägi 2016).

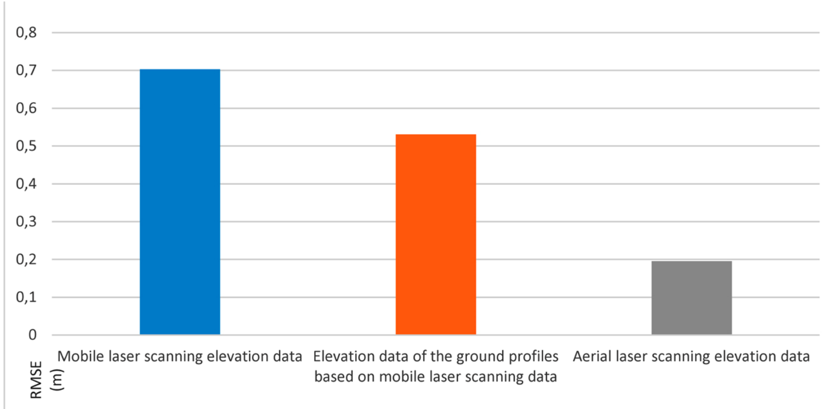

Fig. 7. Comparison of mean elevation data RMSE's of all the sections using different measuring methods

It was found that RMSE of mobile laser scanning data was the largest and RMSE of aerial laser scanning data was the smallest in every section. Authors opinion is that the reason for this is probably the fact, that aerial laser scanning took place in early spring, when vegetation was very sparse. Results show that drawing ground profiles reduced RMSE of mobile laser scanning data in every section. It was also found that, the further from the mobile scanner the larger RMSE of elevation data is. The RMSE of mobile laser scanning data in the II section, which was a crop field, was probably that high, because the crop grew very densely and the top of the crop was automatically considered ground (Kokamägi 2016).

Results show that the accuracy of mobile laser scanning elevation data depends substantially on the density of vegetation in scanned areas. On this basis it can be concluded, that the most reasonable time to conduct mobile laser scanning would be during a season, when vegetation is the sparsest. It can also be concluded that drawing ground profiles makes mobile laser scanning data more accurate (Kokamägi 2016).

References

Alho, P.; Kukko, A.; Kaartinen, H.; Hyyppä, J.; Jaakkola, A. 2009. *Application of boat-based laser scanning for river survey* [online], [cited 02 May 2016]. Finland. Available from Internet: http://onlinelibrary.wiley.com/doi/10.1002/esp.1879/epdf

Kargaja, A. 2011. *Tallinna vanalinn – 3D. Tallinna Linnaplaneerimise Amet. Geoinformaatika osakond* [online], [cited 15 November 2015]. Estonia. Available from Internet: http://www.estgis.ee/wp-content/uploads/2012/04/Ettekanne_3D projekt_A_Kargaja.pdf

Kokamägi, K. 2016. *Mobiilse laserskaneerimise kõrgusliku täpsuse hindamine erineva taimestiku korral*: Bachelor's thesis. Estonian University of Life Sciences, Institute of Forestry and Rural Engineering. Tartu.

Randjärv, J. 1997. *Geodeesia I*. Tartu.

Shan, J.; Toth, C. K. 2009. *Topographic laser ranging and scanning: principles and processing*. United States of America.

IGI. 2016. *StreetMapper 360 specifications* [online], [cited 19 April 2016]. IGI mbH Homepage. Available from Internet: http://www.igi.eu/sm-360.html

Tallinn. 2012. *Tallinna vanalinna 3D mudeli loomine ja avalikku kasutusse andmine* [online], [cited 15 November 2015]. Tallinn. Available from Internet: http://www.tallinn.ee/est/ehitus/Tallinna-vanalinna-3D-mudeli-loomine-ja-avalikku-kasutusse-andmineTallinna-vanalinna-3D-mudeli-loomine-ja-avalikku-kasutusse-andmine

Toompuu, B.; Alanurm, K. 2013. *Laserskaneerimise andmete ja tehnoloogia kasutamine Eestis*: Bachelor's thesis. Estonian University of Life Sciences, Institute of Forestry and Rural Engineering. Tartu.

Vosselmann, G.; Maas, H. G. 2010. *Airbone and terrestrial laser scanning*. Whittles Publishing.

Web mapping service of Estonian Land Board [online]. 2016 [cited 27 April 2016]. Available from Internet: http://xgis.maaamet.ee/xGIS/XGis