The Analysis of GPS Signal Short-term Loss Influence on the Accuracy of Mobile Laser Scanning Data

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SUMMARY

Investigation results of mobile laser scanning data accuracy obtained for a nonlinear road with a length of 1 km are presented. Accuracy was estimated for 2 data sets. In the first case all data obtained in field work were used. In the second case GPS signal did not take into account on observable road area when data processing. Data binding to external coordinate system was carried out using data of near areas processed with taking into account a GPS signal. Removal of GPS data allowed simulating GPS signal loss occurred at scanning of tunnels. For adjustment coordinates of control points were additionally measured by total station. The estimation of horizontal position was implemented on the basis of road surface marking measurement and road signs. The estimation of high-altitude position was implemented on the basis of measurements of points located on both sides of the road through each 50 meters. Mobile laser scanning was done by Lynx M1 Mapper system. The mobile scanning system was calibrated in advance.

The first scanning was carried out in a forward direction, the second one in a backward direction. The main goal of analysis was to determine the GPS signal loss influences to the quality of obtained data. In case of GPS signal losses coordinates of a scanning system's motion trajectory are determined by means of the mobile system's inertial navigation system. The more GPS signal loss duration, the lower accuracy of obtained data. Furthermore, the final accuracy significantly depends on how such trajectory will be processed by POSPac MMS software. The results of relative and absolute accuracy estimation of mobile laser scanning data adjustment are given.

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1. INTRODUCTION

Mobile laser scanning is one of the most progressive methods of the surveying. Today there are many different types of mobile laser scanning systems made by various companies. Every year new surveying systems of this type appear but their elements are not essentially changed. The main elements of any mobile laser scanning system are laser scanners, digital cameras, GPS antennas, inertial measurement unit (IMU) and control unit. These devices are mounted on any vehicle. All measurements are made at its movement. Data storage is carrying out in WGS-84 coordinate system. Final accuracy of obtained data can be various depending on technical characteristics of surveying system, surveying area type, weather conditions, number of base stations, data processing software, number of control points which coordinates are measured by terrestrial traditional methods of surveying [5].

Among the above named factors surveying area type has essential influence on quality of signal received by GPS antennas being a part of any mobile laser scanning system. For receiving a good GPS signal carrying out a survey it is necessary to provide open view of sky that is not always possible when surveying of specified areas. Buildings, foliage, tunnels, various constructions interfere a GPS signal. GPS antenna defines scanning system location in space. IMU which main goal is to calculate heading, roll and pitch angles helps to compensate GPS signal short-term loss in such areas. IMU is capable to compensate GPS signal loss in the middle of a trajectory if there is a GPS signal in the beginning and in the end of the trajectory. Especially it is actual when it is necessary to scan tunnels. But the final accuracy also depends on POSPac MMS GPS data processing software. To increase the absolute accuracy of data obtained without GPS signal measurements of several control points by total stations and levels in such areas are carried out. The Analysis of scanning data accuracy obtained when there is a good GPS signal and when there is no that signal [1-4].

2. INITIAL DATA

For analysis a part of mobile laser scanning data with a 1 km length and uniform turn in Novosibirsk region obtained in September 2013 by Lynx M1 Mapper system was chosen. The surveying of the area under investigation was carried out in forward and backward direction. The average speed in forward direction was 47 kilometers per hour. The average speed in backward direction was lowers in 2 times. The surveying in forward direction was carried out from the North to the South. There were no buildings and trees close to the road. It provides a good GPS signal. In Fig. 1 a trajectory in forward direction are showed in green color, a trajectory in backward direction in blue color. A lack of GPS signal in this area was simulated by means of the subsequent GPS data removal. In this case the beginning and the end of such trajectory at a stage of previous data processing were attached to the trajectories obtained by GPS data usage, in other words data obtained only by IMU were used.

After carrying out the survey elevations of the roadbed approximately through each 50 meters on both sides of roads were measured by a total station. Plane coordinates of road surface marking corners and several road signs were also measured. Measurements were implemented for a part of the trajectory located between red lines shown in Fig. 1 for the purpose of absolute accuracy estimation carrying out of mobile laser scanning data adjustment. The processing was carried out in POSPac MMS, Dashmap and TerraSolid software. Accuracy estimation was implemented for the area limited by red lines in the Figure.

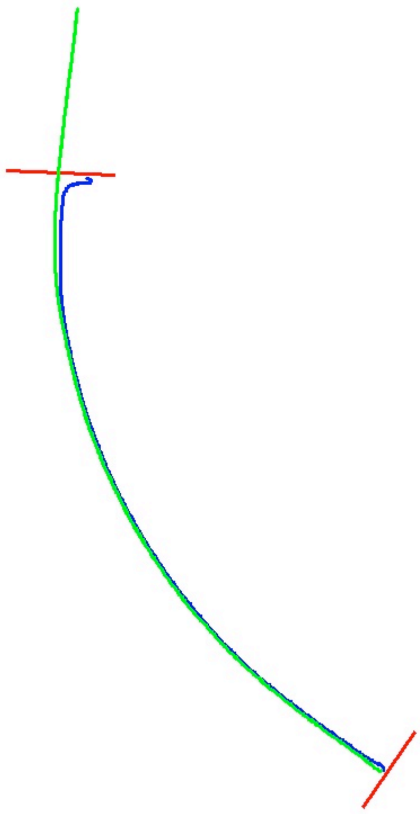

Fig. 1 – Analyzing part of the trajectory

3. DATA PROCESSING

Mobile laser data processing was carried out twice. In the first case the processing was carried out using all GPS data, in the second case without them. Previous calculation of the trajectory was implemented in in POSPac MMS, calibration of laser points in DashMap and TerraSolid software. In the result 2 calibrated laser point clouds were obtained which further take to adjustment. Accuracy estimation was implemented at various stages. At the beginning the relative accuracy estimation was implemented, then absolute accuracy estimation. For this purpose coordinates of control and reference points measured by a total station were used.

In Table 1 the accuracy estimation results of laser point location before adjustment are given. The errors of their location using GPS turned out almost minimum data already at this stage. It caused by a good GPS in consequence of lack of various high-altitude objects and trees. Errors of laser point location obtained without GPS data usage are significantly more. Fig. 2 illustrates distribution of errors along a trajectory for that data in horizontal position, Fig. 3 in high-altitude position. In the Figures errors are given for the area with 1 km length in forward direction and also errors in backward direction.

Table 1 – Relative accuracy estimation of laser point location before adjustment

	With GPS data			Without GPS data		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,026	0,024	0,003	0,169	0,303	0,242
Root mean square error	0,029	0,031	0,004	0,230	0,396	0,277
Maximum error	0,045	0,077	0,020	0,513	0,816	0,555

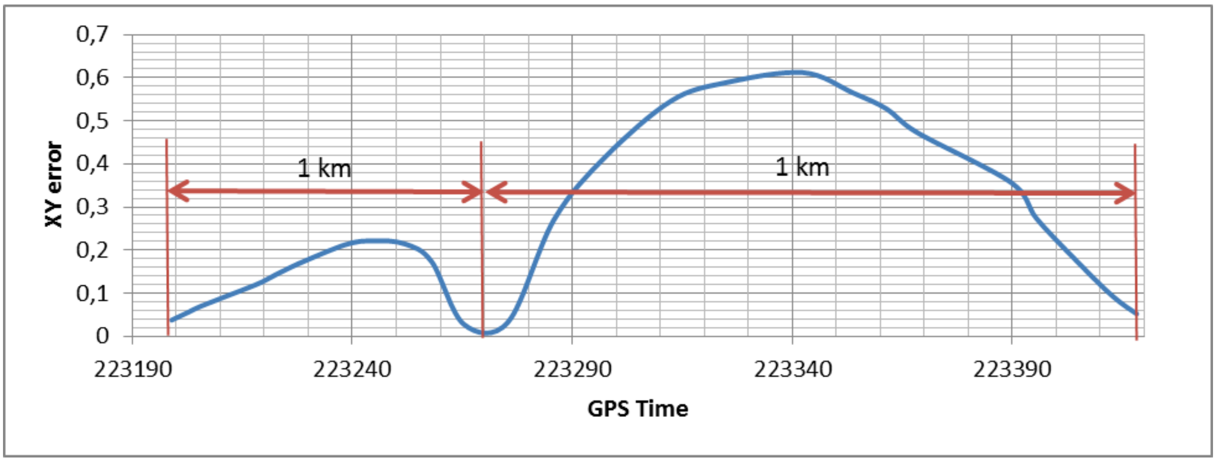

Fig. 2 – Distribution of errors in plane location of laser points, obtained without GPS data usage

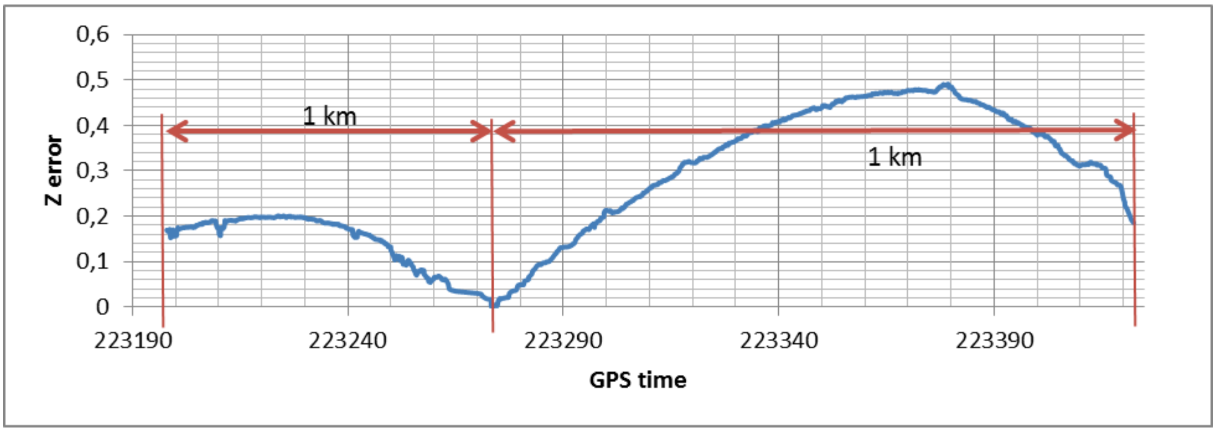

Fig. 3 – Distribution of errors in high-altitude location of laser points, obtained without GPS data usage

From these figures it is seen that maximum errors are located in the center of trajectory in bound of one direction, and minimum ones in the beginning and in the end. In the end and in the beginning the trajectory calculated without GPS data is attached to adjoining trajectories calculated with GPS data usage. The figures also show that errors of trajectory calculation depend not only on passed path, but also on duration of the survey when did not take into account GPS data. The longer do not take into account GPS data for trajectory calculation, the more will be errors.

In Table 2 the results of relative accuracy estimation of laser points adjustment obtained with GPS data usage are presented, in table 3 without their usage. The results show that it is not important for adjustment software which base accuracy has data. Relative accuracy of adjusted data is practically the same.

Table 2 – Relative accuracy estimation of laser point adjustment with GPS data usage

	Control points			Reference points		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,000	0,001	0,001	0,013	0.012	0.001
Root mean square error	0,000	0,001	0,002	0,018	0,014	0.001
Maximum error	0,001	0,002	0,017	0,040	0,021	0.002

Table 3 – Relative accuracy estimation of laser point adjustment without GPS data usage

	Control points			Reference points		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,000	0,004	0,002	0,010	0,014	0,002
Root mean square error	0,002	0,005	0,003	0,014	0,019	0,003
Maximum error	0,003	0,007	0,021	0,025	0,036	0,005

Then absolute accuracy estimation of both data sets was carried out. The estimation was implemented before adjustment after loading control points coordinates in the project and after adjustment. In Table 4 absolute accuracy estimation of laser point location before adjustment, in Tables 5 and 6 after adjustment. In all there were implemented for adjustment of high-altitude position 30 control and 10 reference points, for adjustment of horizontal position 7 control and 3 reference points.

Table 4 – Absolute accuracy estimation of laser point location before adjustment

	With GPS data			Without GPS data		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,046	0,082	0,009	0,578	0,227	0,563
Root mean square error	0,070	0,095	0,012	0.702	0,271	0,566
Maximum error	0,149	0,173	0,036	1,343	0,424	0,635

Table 5 – Absolute accuracy estimation of laser point location with GPS data usage

	Control points			Reference points		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,000	0,001	0,003	0,007	0,017	0,008
Root mean square error	0,000	0,001	0,004	0,009	0,023	0,010
Maximum error	0,000	0,001	0,020	0,012	0,032	0,013

Table 6 – Absolute accuracy estimation of laser point location without GPS data usage

	Control points			Reference points		
	X, m	Y, m	Z, m	X, m	Y, m	Z, m
Mean error	0,000	0,001	0,004	0,021	0,066	0,010
Root mean square error	0,000	0,001	0,006	0,026	0,066	0,013
Maximum error	0,000	0,002	0,027	0,036	0,073	0,022

Table 4 show that there are big errors in absolute location of laser points obtained without GPS data usage. But accuracy of these laser point adjustment using control and reference points can be increased practically to accuracy of laser points adjustment obtained with GPS data usage (Tables 5, 6). Errors in high-altitude position of both data sets on reference points significantly lower that is connected with application of the greater numbers of control points for high-altitude position adjustment. Analyzing accuracy on reference points it can be come to the conclusion that laser points obtained without GPS data usage can be adjusted with the same accuracy as laser points obtained with PS data usage. For this purpose it is necessary to use the greater numbers of control and reference points.

4. CONCLUSION

Thus, GPS signal loss was simulated carrying out mobile laser scanning data saving. Comparable accuracy estimation of data adjustment obtained with GPS signal occurrence and without its simulated occurrence was implemented. In the result of data scanning adjustment accuracy analysis the conclusion about opportunity of laser point coordinates acquisition without GPS data usage with the same accuracy as laser point coordinates with GPS data usage. For that it is necessary to use control and reference points. These investigations show opportunity to apply mobile laser scanning method in areas where there are no GPS signal that is various tunnels.

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