Evaluation of the Positional Accuracy of Trees Derived Using SLAM

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1. Introduction

It is a known fact that forest stands as sets of objects geomorphologically highly structured in connection with variable terrain conditions amplify the influence of specific described factors on positioning accuracy and thus reduce it by moving the value of the resulting positioning error far beyond the permissible deviation.

Traditional methods of positioning, Global Navigation Satellite Systems (GNSS) technology in cooperation with total stations, provides more than a few advantages, but several pitfalls in more complex conditions, too (Keefe et al., 2019).

The trend in collecting information about the forest is currently focused on the application of contactless devices, new technologies and ideally their combinations. The positional accuracy derived from the outputs of carried device will be evaluated in this topic. We assume that it is possible to refine the estimation of determining the position of objects by thoughtful data collection under the forest canopy. The handheld mobile laser scanner ZEB HORIZON which uses simultaneous localization and mapping technology will be used for data collection.

2. Data and Methods

This study was conducted in a managed forest located in Central Slovakia. The forest stand is managed by the Forest Enterprise of the Technical University in Zvolen. Two main research plots were developed in the areas with slightly different conditions. The age of research area 1 (RA1) is 85 years, with a density of 133 trees per hectare, and the age of research area 2 (RA2) is 60 years with a density of 344 trees per hectare. The dominant tree species at both research areas is beech (Fagus sylvatica L.) (45% - RA1, 95% - RA2), at the RA 1 followed by spruce (Picea abies (L.) Karst.) (30%), oak (Quercus petraea) (20%), and fir (Abies alba Mill.) (5%) without the understory, and at the RA 2 followed by fir (Abies alba Mill.) (2%), spruce (Larix decidua Mill.) (2%), oak (Quercus petraea) (1%) with the understory made up by beech (Fagus sylvatica L.) with DBH ≤ 8 centimeters (100%). Every research area was divided into two square plots with dimensions 25 x 25 m.

The positions of 235 trees were measured by the total station on the trunks at the height of 1.3 m above the terrain, and the tree axes determination was done by shifting every point about one-half of its measured DBH during the office work. The DBH were manually measured at the height of 1.3 m using standard steel diameter tape. For each measurement, the 1.3 m height was determined individually by measuring tape. Except for tree position, the four reference spheres were placed on all plot's corners and their polar coordinates were measured.

The experimental data was collected by lightweight handheld mobile scanner ZEB Horizon developed by GeoSLAM Ltd. (UK), consist of a laser scanner, a low-cost Inertial Measurement Unite (IMU), a camera, a data logger, and accessories (S. Chen et al., 2019; Ryding et al., 2015) works on the principles of SLAM. The device was carried by a uniform rectilinear movement over the research area according to predefined marked schemes – dense, medium, and thin research area coverage. The recording of the plots took approximately from 7 to 18 min. The estimation of tree position was connected with the estimation of tree diameter. For this purpose, the DendroCloud software was used (Koreň et al., 2017). Detailed information about the workflow used within the software can be found in Koreň (2019).

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3. Results and Discussion

The use of mapping systems based on simultaneous positioning and mapping as a more favorable alternative to traditional methods of static mapping in a complicated environment has been described in Chen et al. (2018) The work of James & Quinton (2014), Bienert et al. (2006) or Ryding et al. (2015) examine the applications of mobile laser scanners and SLAM technology to various industries, not exclude forestry.

The main goal of the presented work was to evaluate the positional accuracy of objects recorded by alternative approaches in the field of obtaining positional data in the forest environment and to assess the suitability of using technologies in relation to positioning accuracy standards, in relation to a possible increase in the efficiency of mapping work in the forest environment, which will be ensured by accelerating the whole process of collecting information about the environment with the expected achievement of very accurate results. The following is an evaluation of the accuracy of the derived position of trees extracted from a SLAM device (Table 1).

Table 1. Efficiency of field work comparison

Research		Line type	Data acquisition duration [min]	Trees		Positional RMSE				
area	plot			reference	derived	X	Y	Z	Horizontal	Overall
1	A	dense	13	98	96	0.113	0.068	0.501	0.053	0.399
		medium	8		62	0.101	0.051	0.336	0.073	0.337
		thin	7		34	0.042	0.055	0.223	0.093	0.232
	B	dense	14	58	48	0.058	0.058	0.311	0.067	0.324
		medium	11		40	0.070	0.090	0.248	0.089	0.262
		thin	12		48	0.064	0.069	0.252	0.086	0.269
2	F	dense	15	24	25	0.043	0.032	0.149	0.126	0.157
		medium	11		25	0.063	0.038	0.150	0.119	0.166
		thin	9		19	0.042	0.084	0.151	0.068	0.177
	G	dense	16	55	55	0.024	0.064	0.121	0.082	0.137
		medium	18		48	0.060	0.061	0.117	0.108	0.149
		thin	8		47	0.035	0.079	0.113	0.094	0.141
Average:			**11.8**			**0.060**	**0.062**	**0.223**	**0.088**	**0.229**

Considering the positioning error in the direction of the X axes, we were in all cases able to reach values lower than 0.12 m, in the direction of the and Y axes lower than 0.09 m and in the direction of Z axes 0.13 m. The average horizontal RMSE acquires value 0.088 m, and after taking into account the height 0.229 m.

Many authors explore the possibilities of using SLAM in relation to the forest environment and various ecosystems. Nevalainen et al. (2020) in forest work and navigation of logging and transport technologies, Hyyppä et al. (2020) compares SLAM with other mobile laser scanning technologies in boreal forest conditions, and Ali et al. (2020) examines it in relation to mobile robotics, autonomous management research and forestry.

The time of data acquisition is directly related to the cost of data acquisition. Since the authors use different methods for the collection of HMLS equipment, it is appropriate to point out its effectiveness by calculating the time for which 1 ha of area can be recorded by the equipment. On the first hand, some works performed relatively long time data acquisition e.g. Chen et al. (2019) 333 min/ha per operator or Ryding et al. (2015) 200 min/ha per operator, on the other hand, some authors decreased data acquisition duration to lower and more effective time period e.g. James & Quinton (2014) 81 min/ha per operator or Cabo et al. (2018) 36 min/ha per operator. Our research achieved very effective acquisition time at the amount of 19 min/ha per operator.

4. Conclusions

In this study, a handheld mobile laser scanning (HMLS) device ZEB HORIZON has been used for mapping and inventory of forest. The goal of this study was to evaluate the positional accuracy of objects in research areas. Reference data were obtained by the total station. The validation of the positional accuracy of the HMLS data was performed by comparing this data with reference data.

Acknowledging the positioning error in the direction of the X-axis, we can achieve values lower than 12 cm, in the Y-axis direction lower than 9 cm and in the Z-axis direction lower than 13 cm. The average horizontal RMSE reaches a value of 8.8 cm, while taking into account the height of the objects, RMSE reaches 22.9 cm. In this study, we achieved a very efficient data collection, and it would be possible to scan 1 ha with this method in less than 19 minutes.

Many authors demonstrated possibilities of the HMLS e. g. Ryding et al. (2015), James & Quinton (2014) or Chen et al. (2019). The study results show that the used HMLS technology appears to be economical and technical solution for planning some forestry activities that do not require millimeter accuracy of measurement. Spatial division of forest stands and objects can help in planning fire-fighting measures, creating digital models, planning logging, etc.

5. References

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