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Research of Possibilities of Technologies of Laser Scanning in State Border Maintenance Works

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Introduction

The activities of the maintenance of the State Border always are related with a specific area and survey of the objects situated there – both in view of surroundings situation changes, and in view of determination of the real state of the State Border and of elements of its fixation – of the monitoring. Survey works here should be regarded as an integral part of monitoring elements of the State Border, as well as an integral part of identification of work volume of recovery – restoration of border line and of its fixation elements and of further restoration work planning. In the activities mentioned, availability of a good and new model of the surface of the Earth to organizers of the measures and works is always desirable as an important integral part. In the practice of the creation and maintenance of the State Border of Latvia until now, for the purposes of creation of the models, traditional survey techniques, classically familiar surveying instruments were used, devoting considerable working time consumption in the territory to be surveyed.

Starting from the beginning of the last century, in the practice of mapping and surveying and in the surveying of State Borders, photogrammetrical surveying or remote sensing technologies, which differed from classically geodetic technologies, were introduced [1;2]. New advantages for creation of the Earth surface models emerged by use of results of the photographing of the surface of the Earth. In the works of State Border, the new technologies were used more and more, but only with the development of the computerization the extent of use of new technologies began to grow rapidly; at the beginning, they showed effectiveness in the cases of creation of models for large territories [3]. Today, laser scanning (or LIDAR) data extraction technology is regarded as an appropriate remote sensing – photogrammetrical technology destined directly for the development of 3D models [4]. In the modern version, this technology combined with results of development of information technologies and their software is also of considerable interest for the State Border installation and maintenance professionals [5]. The achieved speed of performance works, the accuracy indicators obtained and the considerable amount of survey points in the area for large territories together with trend of reduction of costs and of amount of field works comprise good prerequisites for use of these technologies. As well as for measures of geoinformation provision for maintenance of State Border.

In the framework of the research, it is offered to become acquainted with a practical example of use of light aircraft – drone equipped with compact laser scanner for the case of on Latvian – Belarusian border. Firstly, for the development of the surface model of the territory of State border Zone. Secondly, for identification of changes of area in territories, which are difficult to reach in the vicinity of State Border, and in relation to the location of the State border or the elements of its fixation and their physical condition. Thirdly, use of a modern and up-to-date 3D model becomes base of development and implementation of projects of installation/equipping of the State border and of border zone.

The study is carried out by use of laser scanning data obtained by the company SIA "A-GEO" for Latvian – Belarusian border zone, as well as software of computer-aided design of 3D models.

Materials and Methods

Basical integral part of the State Border maintenance works is monitoring of the condition of the State Border line and of its fixation elements. As a result, you need to get convincing information on unequivocal constancy of the location of the State border on the ground or if changes still are detected clear – then how great they are, of what kind they are, and they have to be unequivocally documented [6]. And only after the fixation of the detected changes, their volume and nature in spatial information documents – such as maps, plans or their databases (with lists and tables), further works of border maintenance can be started. Examples of such works are the restoration of border markers or border posts, renewal of location of border line. Also in these work performance processes, geoinformation provision support is essential both in their planning stages and in the course of work organization, and in particular, for the checks of work results and for fixation in the report documents, as well as at the end stage, for documenting renewed border sections or fixation points in accordance with State Border documentation requirements [7].

At the same time, the available theory and practice of laser scanning works points to the possibility of a significant benefit, if they are used in border maintenance geoinformation provision works. Firstly, properly organized laser scanning results allow you to create multiple high-quality 3D terrain models for the selected border area. Results of one laser scanning process allow to obtain the terrain surface model (including surface of all natural and man-made objects), as well as the terrain model of this territory (excluding surface of all natural and man-made objects from the previous model) [4]. The results enable also good recognition and classification of objects on the surface of the Earth [8]. Essentially, this technology enables replacement of works of topographic survey of large extent in the area [8], ensuring high-quality implementation exactly in sections of the border, which are hard to reach, and there are many such sections on the border of Latvia.

3D models of the surface of Earth, where objects situated on the surface are included or without them, may be regarded as the most appropriate products for the evaluation of the situation of the border. These models allow to assess qualitatively the situation in the region, to identify the changes, which have occurred, and the parameter estimates (including plant cover parameters) [4], also to recognize the elements of fixation of the border, their location and to try to determine the condition of their conservation, or to identify their loss.

Authors of the paper set the target – to approbate practically and demonstrate possibilities and results of use of the new LIDAR technologies in the field of maintenance of the State Border.

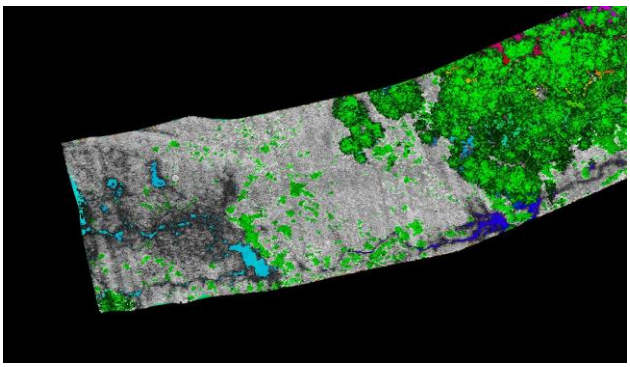
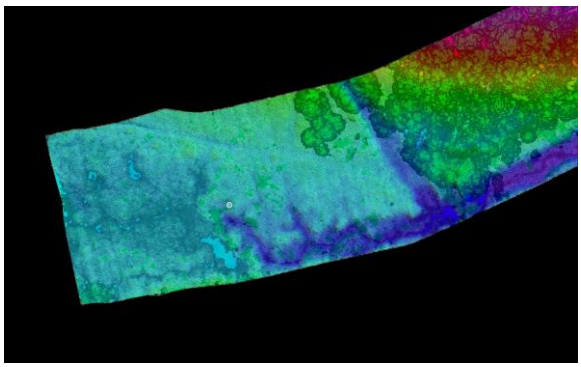
For the execution of works, the unmanned aircraft "dji MATRIX 600" with GPS and INS equipment, software for computerized flight stability and software for provision of self-contained flight was used. Laser scanner "YellowScan Mapper" with software for scanning process control and data storage is installed as scanning equipment. Software "Yellow reader" on QGIS base is used as a software for first stage processing of results. Path alignment "septentrio post nav" software.

The programmed average density of scanning data – density of points – 30 points per m ^{2}. Area of scanned territory 750 ha to 150 km along the State Border.

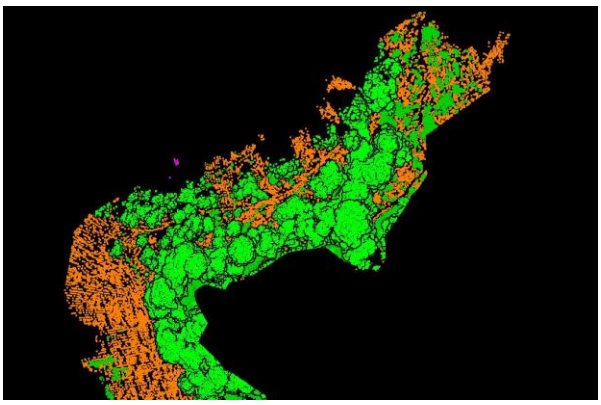
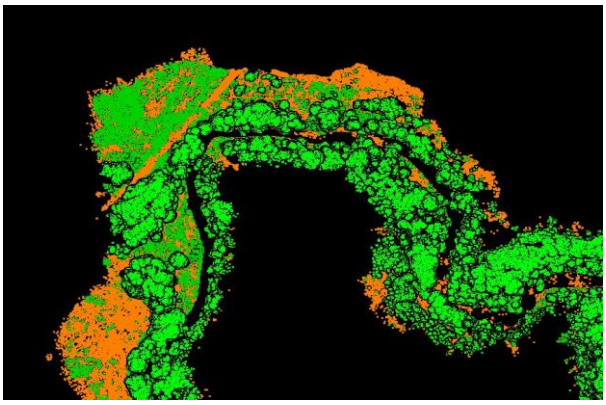
Actual durations of performance of works - flying 17 days, first stage processing 7 days, topographic plan 2 months. Average density of points obtained – 40 points per m^2.

Results and Discussions

The resulting point clouds were prepared for the further processing by use of diverse first stage processing and representation settings. Research took place by selecting more complicated border sections, mainly with significant plant cover – the amount of trees and individual boggy places out of the total material. Samples of depiction of point clouds are given in figures 1; 2; 3; 4; 5; 6; 8; 9.

Figures 1 and 2 - *Pictures of point cloud of scanning of the border section 0827 sound in various versions.*

Figures 3 and 4 - *Depiction of classified point clouds of scanning of border sections in sections 182 and 78.*

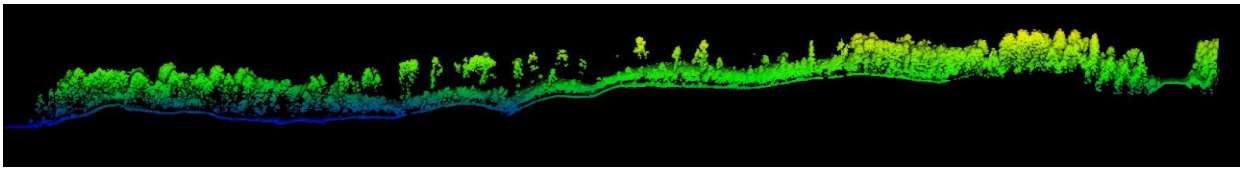


Figure 5 - *Profile of scanning of border (profile section) in section 145-146 - black background.*

Figure 6 - *Profile of scanning of border (profile section) in section 145-146 - light background.*

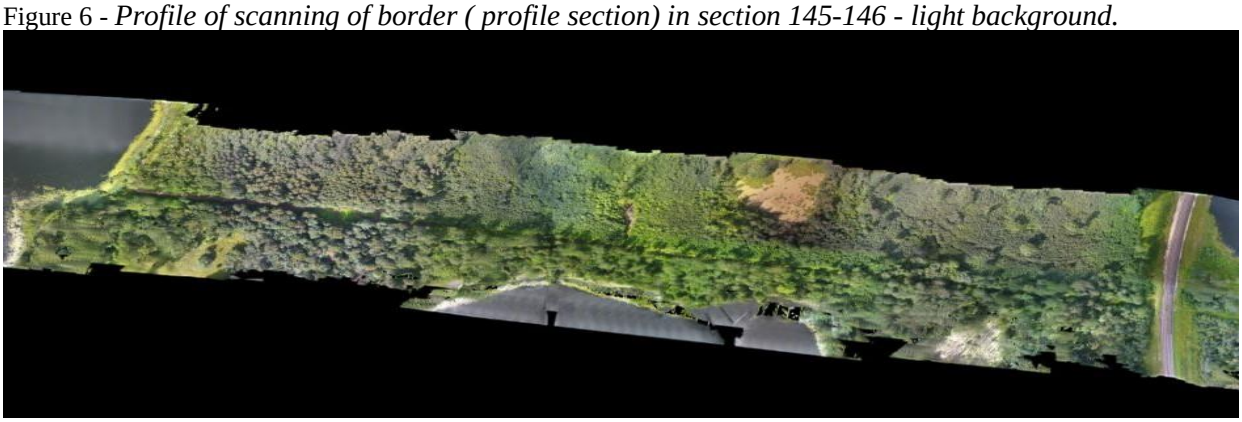


Figure 7- *orto photo of section 145-146 of scanning of border.*

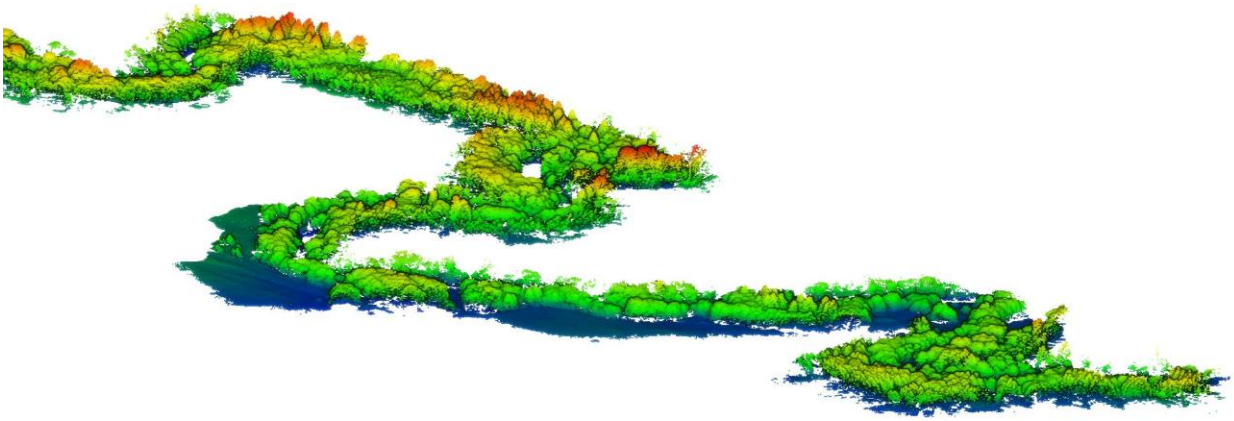


Figure 8 - *Depiction of results of scanning of border in section 78, image of classified point cloud, light background.*

In work processes, the above-mentioned point clouds are transformed to vertical – perpendicular against the scanning direction profile sections (an example is given in the figure 10) or to selected profile sections parallel to the border or along the border line – for example pictures 5 and 6.

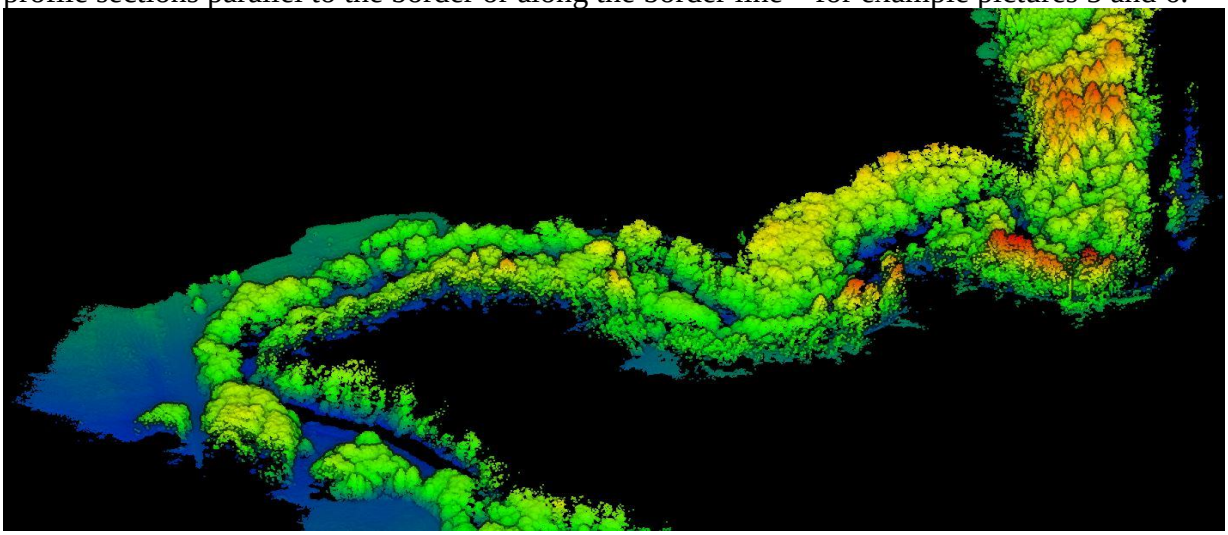


Figure 9 - *Depiction of results of scanning of border in section 78, image of point cloud, dark background*.

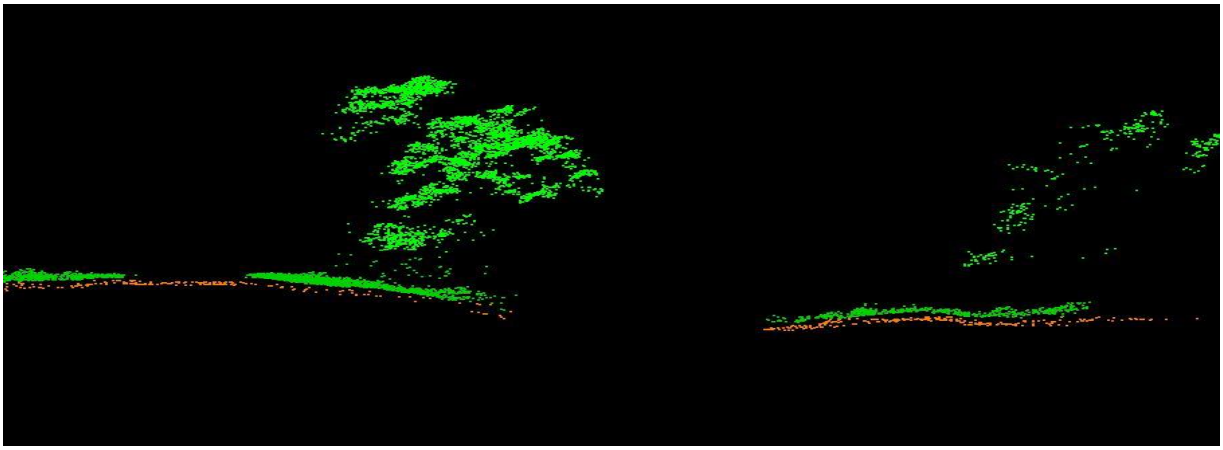


Figure 10 - Depiction of results of scanning of border in section 78, image of profile section

Thus significant advantages for identification of the terrain and of objects situated on it, as well as for survey of their parameters were marked and checked. When for the making information more exact, orthophoto created for the above-mentioned territory were added, which were produced by use of aerial photographing that was carried out from unmanned aircraft (Pictures 7; 14; 15; 16; 17; 18) in the same time with scanning, amount of details in information and its credibility increased significantly [1]. There were border posts and other region objects of the area visible and clearly

identifiable on those images. They often could not be clearly identified in scanning even then, when some reflection of scanning was received also from these objects. All the initial data sets and point clouds and orthophoto with great precision were compatible with GIS software capabilities – so combining possibilities of both information sources and also checking them when comparing in poits of spatial coincidence. In the following steps, by use of GIS software these input data sets were successfully aligned with the georeferenced demarcation document data – mainly maps and coordinate catalog data, as well as the schemes of border post protocols, and evaluations of visual matches - mismatches according to corresponding border sections and their fixation elements were achieved.

The next step, which enabled additional possibilities of border location monitoring, especially of ditches, brooks and rivers, along which the State Border is delimited, is related to the processing of point clouds - transformation into 3D terrain models formats. Examples in figures 11; 12; 13. Here was a chance to determine the lowest surface point locations – which marked the ditches or watercourse coast lines, also in swamps the lowest points – badly visible sections of flooded watercourses – so the possible location was determined in these sections. Also, these models became compatible with the demarcation data – maps by use of GIS capabilities and allowed to identify situations and border line match or mismatch and their parameters.

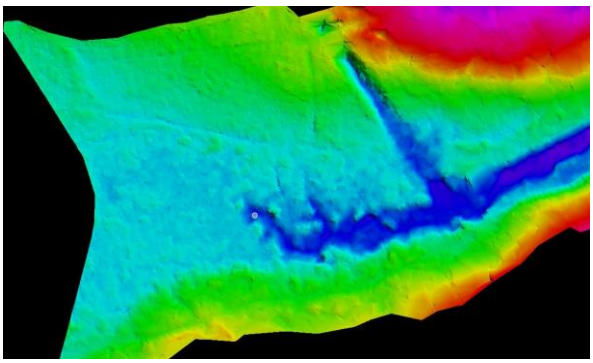


Figure 11 - *Terrain model of border section 0827*.

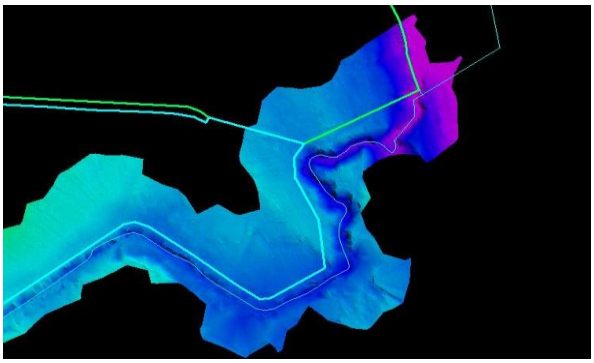


Figure 12 - *Terrain model of border section 182*.

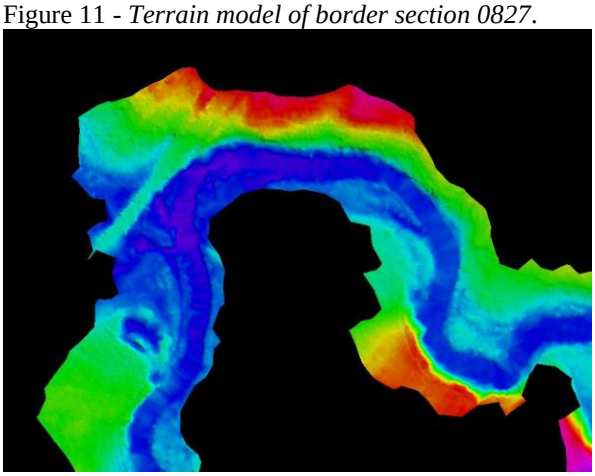


Figure 13 - *Terrain model of border section 78*.

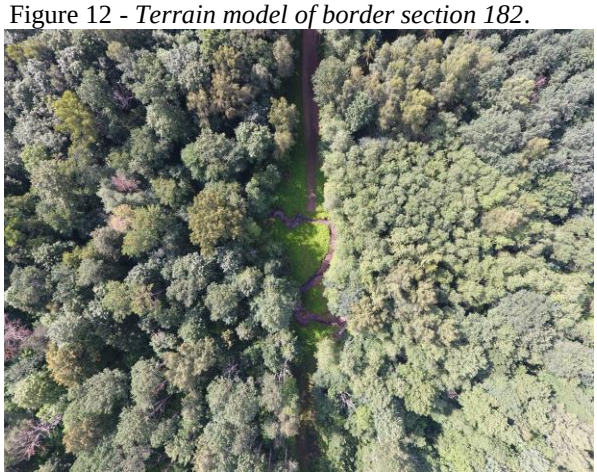
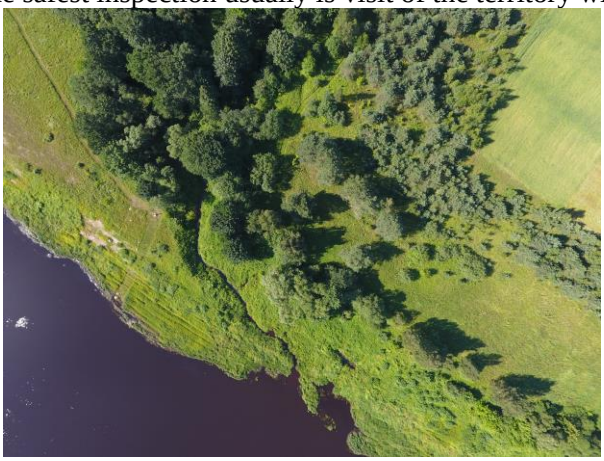


Figure 14 - *Orto photo for section 45-46 (brook mean*ders)

Figure 15 - *Orto photo for section 0810 (border po*sts at a river) Figure 16 - *Orto photo for section 0827 (marshy sec*tion)

In subsequent laser scanning point cloud processing processes, by use of the terrain models obtained from them in the automatic mode (using software functions), operations of generation of drawing of terrain – horizontals were performed – so terrain generation images were obtained (*Figure 19*). Initially, this result of generation is usually robust and hard to read, but by use of the manual processing, high-quality terrain drawings, which correspond to the map or plan, which can be added to the sets of information for comparison with the demarcation materials and for creating new topographical plans or maps. It should be taken into account that, also in these cases, the elaboration of terrain drawing is connected to the large additional amount of manual work and involvement of qualified cartographers – therefore, such jobs are not done without special necessity and more often they are being done only on certain - selected border sections, for example when there is a clearly defined necessity to create a topographical plan or map (Figure 20). In the next step, by use of laser scanning input materials and products made from them, as well as the available aerial photographing materials and orthophoto produced from them, it is possible to carry out valuable development of topographic plans and maps. So the classic survey technologies are replaced [3] (Figure 20). In these cases, the cartographic material is obtained by minimizing the survey works on the ground – work is done mainly in the office. We must always remember, however, that by creating topographical plans in this technology, it is necessary to think very carefully and to carry out safe check – control procedures in order to preclude possibility of human factor errors [9;10]. There the safest inspection usually is visit of the territory with already prepared product.



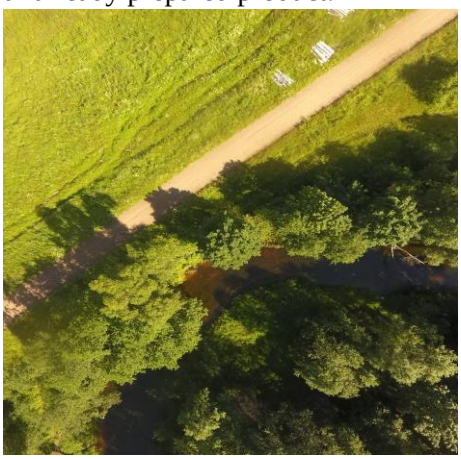
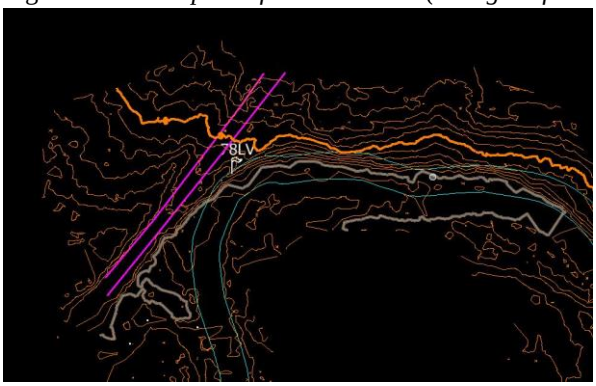


Figure 17 - *Orthophoto for section 182 (changes of brook inle*t) Figure 18 - *Orthophoto for border section 78*



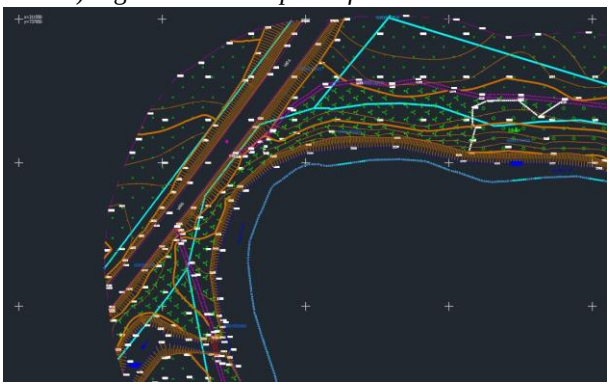


Figure 19 - *Generation of terrain image of border section 78.* Figure 20 - Topographical survey *for border section 78*

By aligning and comparing the results obtained in the original point cloud variations and by further processing these point clouds in surface models of specific territories, and by generating terrain drawings, as well as by creating results of valuable topographical survey, data sets are acquired for further comparison of information obtained with the border depicted in the demarcation documents of the State Border. Due to widespread use of GIS software possibilities, such comparison can be carried out efficiently and quickly, at the same time ensuring obtaining of diverse measurements and characteristics for illustration and justification of results of the comparison.

Experience shows great efficiency of the identification of location of State Border line – its relationship with the new situation in the area. Particularly significant time savings are achieved in identification of shorelines of watercourses of the border, at the same time the obtained accuracy of the depiction is already by order higher than that of depiction on demarcation map. For identification of border markers and assessment of their condition, better results were provided by orthophoto material in the same time (only when the border markers were in open places) – scanner data could give a good result, if scanning density would increase at least 2 x.

An essential role of data and of products developed from them is providing the identification of the changes of the situation in the border zone where a good result is obtained in a relatively short time.

The next benefits are associated with the planning, organization and implementation of maintenance – restoration works. The new elaborated material is effective tool for remote evaluation of possibilities of access for humans and work equipment, roads, paths and their real situation. This also applies to the renewal work planning, determination of the amount of works, in particular excavation and plant cover cleanup work because scanning data are showing plant cover parameters very well, are separating bushes and trees and are showing their heights widths of foliage and even the size of trunks of trees.

Conclusions

When we get acquainted with the results obtained in the course of the experiments, following conclusions can be drawn:

1. Possibilities of laser scanning technologies can provide substantial qualitative and quantitative improvements in the geoinformation provision of the State border maintenance works;

2. When we started to use laser scanning technologies, where for data acquisition modern drone – aircraft platforms with automated flight control options and appropriate laser scanning equipment are used, costs of works become significantly lower with increased diversity of performance of works and operative performance;

3. The currently available experience potential for use of LIDAR technologies in the maintenance of the State Border, is in the original development phase and the accumulation of experience in the case of the border of Latvia;

4. The results of possibilities obtained as a result of laser scanning and of performed works, as well as the amounts of their future use and efficiency in the measures of maintenance is an initial validation phase, it is therefore necessary to continue their research, development, and accumulation of practical experience.

References

1. Ratkevičs.A. Celms.A. Puķīte.V. (2017) Valsts robežas demarkācijas uzmērīšanas darbu kvalitātes novērtējums, pielietojot tālizpētes materiālus / Aivars Ratkevičs, Armands Celms, Vivita Baumane // Ģeogrāfija. Ģeoloģija. Vides zinātne: referātu tēzes, Rīga, Latvija, 30.janv.-7.febr., 2017 / Latvijas Universitāte (Latvijas Universitātes 75. zinātniskā konference). Rīga, 2017. 263.-264.lpp., URL:

https://www.geo.lu.lv/fileadmin/user_upload/lu_portal/projekti/gzzf/Konferences/Zin_konf_tezes_GZZF_2017_1105.pdf ISBN 9789934556227.
2. Ratkevičs A., Celms A., Reķe I., (2016) The choose of Latvian state border demarcation geodetic substantiation and impact on future work quality.
3. Ratkevičs.A. Celms.A. Puķīte.V. (2017) Remote sensing methods and materials usage in state border demarcation works = Використання методів та матеріалів дистанційного зондування для демаркації державного кордону = Использование методов и материалов дистанционного зондирования для демаркации государственной границы / A. Ratkevičs, A. Celms, V. Baumane // Сучасні досягнення геодезичної науки та виробництва: Збірник наукових праць Західного геодезичного товариства УТГК. Львів,2017. Вип.1(33), с.172-178, URL: http://vlp.com.ua/node/16934 ISSN 1819-1339.
4. Ratkevič.A. Celms.A. Veliks.A. (2017) Virsmas uzmērīšana pielietojot bezpilota lidaparātu ar lāzerskanēšanas iekārtu, Ģeogrāfija. Ģeoloģija. Vides zinātne: referātu tēzes, Rīga, Latvija, 30.janv.-7.febr., 2017/ Latvijas Universitāte (Latvijas Universitātes 75. Zinātniskā konference).Rīga,2017.265.-266.lpp.,URL:https://www.geo.lu.lv/fileadmin/user_upload/lu_portal/projekti/gzzf/Konferences/Zin_kof_tezes_GZZF_2017_1105.pdf ISBN 9789934556227.
5. Бурбан П.Ю. Опыт использования спутниковых технологий и данных дистанционного зондирования Земли при демаркации государственной границы. «Земля Беларуси». №3, Минск 2012 г. Стр. 6-8.
6. Архипов А.И., “Установление и содержание государственной границы Республики Беларусь (1991-2010 гг.)”: учебно-методическое пособие, Орша, Оршанская тип., 2011. — 264 с. ISBN 978-985–7016–04–4
7. Бурбан П.Ю. Демаркация российско-латвийской границы, Вестник Россреестра, №1(3), 2010 . С.39-42.
8. Kodors.S., Rausis.A., Ratkevics.A., Zvirgzds.J., Teilans.A., Ansone.I.(2017) Real estate monitoring system based on remote sensing and image recognition technologies / Procedia Computer Science. Vol. 104: Proceedings of Riga Technical University ICTE 2016; (2017), p. 460–467. DOI: 10.1016/j.procs.2017.01.160,URL:http://dx.doi.org/10.1016/j.procs.2017.01.160,URL:https://www.scopus.com/inward/record.uri?eid=2s2.085016078664&doi=10.1016%2Fj.procs.2017.01.160&partnerID=40&md5=0f9eed2cac38c71cf99aaae19c951433,URL:http://gateway.webofknowledge.com/gateway/Gateway.cgi?GWVersion=2&SrcAuth=Alerting&SrcApp=Alerting&DestApp=WOS&DestLinkType=FullRecord;UT=WOS:000399478800062
9. Ratkevičs A., Celms A., Kukule I., (2016) Geodetic base preparation for state border demarcation, Proceedings “Modern advancements on geodetic science and industry” volume II (32) of Western Geodetic Society of Ukrainian Society of Geodesy and Cartography, Lviv Polytechnic National University press, Lviv, 2016, 45 - 56 pp.
10. Бурбан П., Раткевичс А., (2016) Современные технологии при создании общего геодезического обоснования демаркации государственной границы. Geoforum 2016, Lvova, Современные достижения геодезической науки и практики, Выпуск 31, стр. 16, ISSN 1819-1339

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Maintenance of the state border is always related to the specific territory and the surveying of the objects therein, identifying both the situation of the surrounding area and the real situation of the state border and its consolidation elements. In the past traditional surveying techniques have been used with significant work-time consumption in the area under survey. Today laser-scanning (or LIDAR) data acquisition technology is considered as a modern and suitable technology for the development of 3D models. The research examines the results of practical experiments of Latvian specialists in the use of LIDAR technology in the state border maintaining, evaluating the results obtained and outlining its prospects for use in conjunction with GIS capabilities.