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MODERN METHODS OF PROCESSING AND CREATING A DIGITAL TERRAIN MODEL

Nowadays the requirements for topographic and geodetic products are becoming more important and gaining direct economic importance due to the high rate of market development. The main requirement remains the reliability and differentiation of the results of cartographic materials, and the most important issue is the accuracy of the developed products. The accuracy is affected by a variety of factors, depending both on the means of measurement and the type of processing. This paper presents an overview of modern survey methods for the projecting of linear structures based on the example of road sections in Almaty. Currently, the design of roads is, as a rule, based on topographic survey data, performed by traditional geodetic instruments. It is necessary to apply the automatic projecting system containing components of software, information, technical and organizational support to increase the quality of solutions on projecting objects. This article considers automated approaches for efficient data processing, comparative analysis of software complexes that are widely used to create digital terrain models, their ability to support and create three-dimensional models, import of point cloud, a way of constructing relief, importing and processing initial data.

Key words: digital terrain models, processing data, roads.

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Жергілікті жердің сандық үлгісін құру мен өңдеудің заманауи әдістері

Қазіргі кезде нарықтың даму жылдамдығының өсуімен байланысты, топогеодезиялық өнімдердің берілетін талаптары күшеюде және экономикалық маңыздылығына тікелей әсер етуде. Сондықтан картографиялық мәліметтер нәтижесінің саралануы мен нақтылығы негізгі талаптармен сақталады, бірақ өте маңызды болып құрылған өнімнің дәлдігі болып табылады. Дәлдікке әртүрлі факторлар, өлшеу құралдары және оларды өңдеудің әртүрлі үдерістері әсер етеді. Берілген мақалада жол құрлысын жобалау үшін заманауи әдістерге, Алматы қаласының автомобиль жолдары мысалында алынды. Қазіргі кезде автомобиль жолдарын жобалау, негізінен топографиялық түсіріс мәліметтерімен, дәстүрлі геодезиялық аспаптар арқылы жүзе-

ге асады. Нысандарды жобалаудағы жобаның шешімінің сапасын көтеру үшін міндетті түрде автоматтандырылған жобалау жүйесін қолдану қажет етеді, оның құрамына бағдарламалық, ақпараттық, техникалық және ұйымдастыруды қамтамасыздандыру кіреді. Бұл жұмыста мәліметтерді тиімді өңдеу үшін автоматтандырылған әдістері қарастырылды, оған жергілікті жердің сандық үлгісін құру, олардың үш өлшемді үлгілерді құру мен қолдау мүмкіндіктері, нүктелік бұлттылықтарды импорттау, жер бедерін құру мүмкіндіктері, бастапқы мәліметтерді өңдеу және импорттау үшін кеңінен пайдаланатын бағдарламалық кешендерге салыстырмалы талдау жасалды.

Түйін сөздер: жергілікті жердің сандық үлгісі, мәліметтерді өңдеу, автомобиль жолдары.

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Современные методы обработки и создания цифровой модели местности

В настоящее время в связи с высокими темпами развития рынка требования, предъявляемые к топогеодезической продукции, все более усиливаются и приобретают непосредственное экономическое значение. При этом основным требованием остается достоверность и дифференцированность результатов картографических материалов, а также наиболее важным вопросом является точность создаваемой продукции. На точность влияют самые разнообразные факторы, зависящие как от средства измерения, так и вида процесса их обработки. В данной статье представлен обзор современных методов съемки для проектирования линейных сооружений на примере участков автомобильных дорог города Алматы. В настоящее время проектирование автомобильных дорог осуществляется, как правило, на основе данных топографической съемки, выполняемой традиционными геодезическими приборами. Для повышения качества проектных решений на объектах проектирования необходимо применять систему автоматизированного проектирования, содержащую в своем составе компоненты методического, программного, информационного, технического и организационного обеспечения. В работе рассматриваются автоматизированные методы для эффективной обработки данных, сравнительный анализ программных комплексов, которые широко используются по созданию цифровых моделей местности, их возможность поддерживать и создавать трехмерные модели, импорта облака точек, способ построения рельефа, импорта и обработка исходных данных.

Ключевые слова: цифровая модель местности, обработка данных, автомобильные дороги.

Introduction

Over the past decades, the world is rapidly moving towards a new type of economy, where digital technologies are becoming the main tool for its formation. The state program “Digital Kazakhstan-2020” promoted the digital transformation and is the main factor of technological changes, as well as a condition for ensuring the competitiveness leading to the restructuring of all economic and production processes, and the increase of productivity. In modern conditions, information technologies play an important role in the work of the private and public sectors, which is the basis for the transition to a digital state (the State Program “Digital Kazakhstan” for 2017-2020).

The demand on various services needed for Earth surface surveying in the geospatial market is quite high. Therefore, the pace of information collection and processing should be at an appropriate

rate. Typically, these processes are local in nature, affecting small areas scattered in space, and are quite numerous. (E. Levin, 2017:206).

The purpose of this work is to study the modern methods of data collection and comparative analysis of survey results to obtain an estimate of accuracy and improve performance. The goal of our work was to choose a method of obtaining a digital terrain model (DTM) that would reduce the processing time and at the same time leave the reliability and differentiation.

The creation and development of construction can be carried out with the help of classical methods of geodetic work, with modern geodetic instruments. The most elaborated from the technological point of view are the measurements of the road coordinates carried out by the traditional geodetic methods using the electronic tachometers and digital levels (S.Babic, 2015, Volume 1). The time-proved solu-

tion provides millimeter accuracy, but it requires significant costs to create a high-precision coordinate space in the area where the measurements are made (SCNP-02-036-02.) Moscow, TsNIIGAiK, 2002:6).

The validity of the engineering solutions should be confirmed in the comparison projects for all parameters including the costs for the construction, maintenance and repair of the road, the transport and operational qualities of roads and road facilities, road safety, the impact on the ecological system, contribution to the economic and social and cultural development of the region and other factors (SNIIP of the Republic of Kazakhstan 03.03-09-2006 Highways).

According to the Law of the Republic of Kazakhstan "On Roads", the technical solutions for the location of roads in the area, its main structural elements should be economically justified, should include the use of advanced energy and resource-saving technologies that promote quality and safety of road traffic. Design, construction, reconstruction, repair and maintenance of motor roads are carried out in accordance with established requirements and norms, with the use of materials, instruments, equipment and measuring instruments authorized for use to achieve the high transport and operational parameters of highways (speed, evenness, durability,

increased conditions for the safety of motor vehicles) (Law of the Republic of Kazakhstan, 2001: N 245).

The use of data collection methods based only on ground surveys increases the cost of work. In these circumstances, the use of easily transportable, remotely controlled aircraft (unmanned aerial vehicles) equipped with the required imaging equipment allows to carry out all the necessary stages of the project very quickly and to flexibly regulate the current technology, even in the absence of stable weather conditions for traditional shooting (A.Sechin,2011). Aerial photography, with an unmanned aerial vehicle (UAV) can provide the informative and accurate orthophoto coverage in the shortest possible time due to the appearance of new processing algorithms changing the methodology. The technology is used for massive mapping and 3D modeling of the linear infrastructure objects (roads and railways, power lines, city streets), area objects of complex structure and high detail of the research - creation of a digital model.

Methods of research

T.Luhmann introduced a categorization scheme of measurement techniques that trades sizes of the measured objects versus required accuracy. Modification of this scheme is presented in Figure 1 (E. Levin, 2017:205; T.Luhmann, 2006: 26).

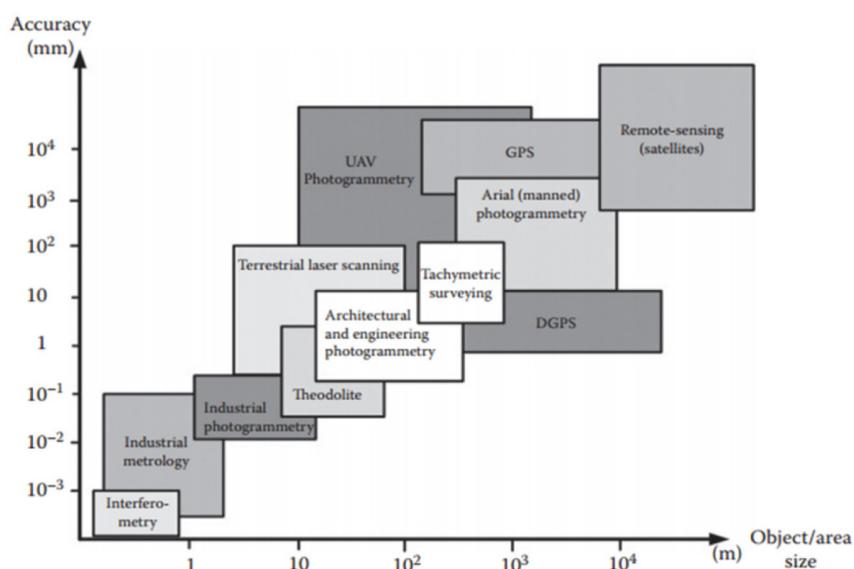


Figure. 1 – Classification of measurement techniques

Three methods of topographic and geodetic work were considered:

– Tachometric survey (traditional method);

– Aerial photography using an unmanned aerial vehicle;

– Mobile laser scanning.

1) The traditional method of surveying using the electronic tachometers was considered as a cheaper and simpler method of obtaining the data (A.Lofton,2016). However, the time costs, loss

of completeness and quality of the data collected, as well as subjective perception of the road infrastructure elements by the direct executors made this method to be brought to the background.

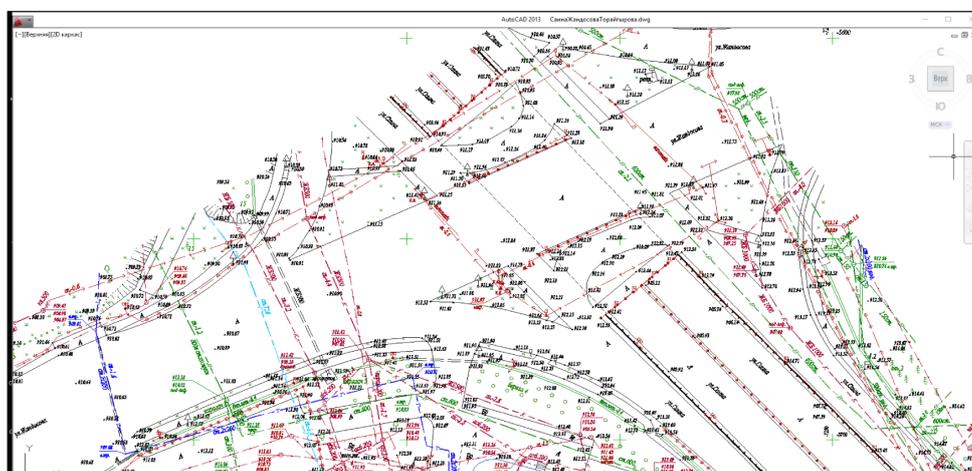


Figure 2 – Fragment of tacheometric survey of the road section of Almaty city

2) Aerial photography using an unmanned aerial vehicle

Qualitatively new method of obtaining information about this area is the use of digital aerial photography with UAVs (H.Eisenbeiss, 2012) It is worth noting that in comparison with the satellite images and traditional aerial photography, aerial photography with UAVs has significant advantages. First, the high resolution of the images obtained: maximum - up to 1-2 cm (at flight altitudes of 30-50 m),

average – 8-10 cm (at an altitude of 250-300 m). Secondly, the pictures can be taken and be initially processed in a very short time without leaving the place of survey. Third, the possibility of surveying the local and hard-to-reach areas, the space imagery and traditional aerial photography of which are not cost-effective. Fourth, the quality of images obtained does not depend on the cloudiness, since it is possible to shoot under the clouds on cloudy days, which is especially urgent (Y. Polyakova, 2012.)



Figure 3 – Fragment of orthophoto of the road section on the territory of Almaty

As for aerial traffic safety issues, small UAVs are not equipped with air traffic communication equipment and collision avoidance systems, compare to manned air-crafts (I.Colomina,2008). Therefore, due to the lack of communication with air traffic authorities, small UAVs are restricted to flight in line-of-sight (LOS) and to operate with a backup pilot. Besides UAV control stations communication frequencies (typically 30–40 MHz) signals may interfere with another civil segment device (remote controlled cars and hobbyist aircrafts), therefore there is the possibility of signal jamming (E. Levin, 2017:207).

3) Survey of the site using a mobile laser scanner.

Mobile laser scanning is the best one for measurements of linearly extended objects and, at first, the roads. This method is effective in terms and quality of the data obtained. The problem of constructing the three-dimensional digital models has become much simpler, allowing to create a high-precision digital model with spatial coordinates in the form of a set of points. If the survey of a large constructed area with tachometers can take weeks, the mobile scanner can make it in a matter of hours.

The main reason for choosing a mobile laser scan for surveys is to perform the field measurements with very high speed and detail (Sarychev D., 2013).

Advantages of mobile laser scanning systems also include:

1. Achieved relative accuracy – up to 10 mm.
2. The result of scanning is a very dense set of points – thousands of measurements per 1 m², even at high shooting speeds
3. Ability to install on various vehicles.
4. Economic data processing.
5. Fast and safe shooting of roads and road infrastructure.

Table 1 presents the parameters characterizing the traditional technology of geodetic survey and survey using MLS and UAV. Analysis of the data of Table 1 shows that the traditional method significantly loses the method of MLS and UAV in many respects precisely when shooting linear long objects. In addition, in the works (A.Baigulov, 2013; Sarychev D. 2013; V.Safar, 2014), the authors identified the following advantages mobile laser scanning in comparison with other methods of engineering and geodetic research.

Table 1 – Comparison table of survey methods

Parameters	Survey method		
	UAV	MLS	Tacheometric survey
Productivity	for a resolution of 10 cm / point - up to 30 km ² / departure;	300 thousand measurements per second	300-500 pickets / day
Organization of shooting	Does not affect the movement	Does not affect the movement	It is necessary to block the movement
Error	10-30 mm	5-20 mm, depends on the quality of the plan-altitude basis, the quality of the GPS signal	5mm – 5 cm (depends on stroke length)
Productivity per day	70 km	100-250 km	relatively
Density of a point model	-	2 points on m ²	1 point on 100-200 m ²
Digital model accuracy	15-20 cm	5-10 cm	relatively
The width of the swath	30-50 m	50–250 m	no more 100 m

As can be seen from Table 1, the MLS method is the most effective in accuracy and speed, and the UAV method is economically advantageous. The traditional method gives the necessary accuracy, but significantly lower performance indicators.

The obtained survey data are used for further planning and modeling of the transport infrastruc-

ture. First of all, it is necessary to create a DTM that will meet the requirements and conditions for design.

Features of creating a digital site model

Digital models significantly reduce the time and labor costs compared to the traditional technology of obtaining marks from topographic

maps and plans (I. Zhurkin, 2012: 32). Creation of a digital terrain model with high accuracy of displaying reality despite the variety of different software products is a priority task (Ch. Frueh, 2003)

With the appearance of new methods for collecting the geodetic information, satellite imagery, airborne, mobile and terrestrial laser scanning, it became possible to automate the creation of 3D site models (Zhilin Li, 2005:5).

We used the following softs to create digital models.

1. Agisoft Photoscan
2. Erdas Imagine

3. Fugro Viewer

Program for compare the obtained digital models of Cloud Compare

1) Agisoft PhotoScan program is a universal tool for generating the three-dimensional models of the photography objects surfaces from the photo images of these objects (V. Seredovich, 2012). PhotoScan is successfully used both for creating the models of things and objects of different scales - from miniature archaeological artifacts to large buildings and structures, and for building the site models based on aerial photographs and generation of height matrices and orthophoto maps based on these models.

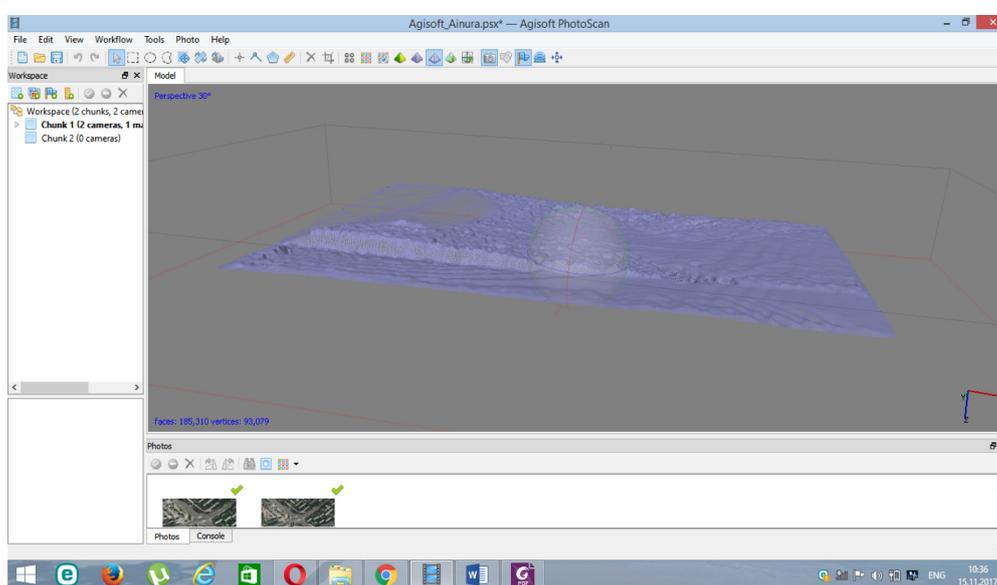


Figure 4 – Fragment of processing Agisoft Photoscan program

As a result of processing of photography materials, it becomes possible to get the three-dimensional site models in TIN and DEM formats; 3D site models with a texture from the original photo images; 3D site models in the form of point clouds; orthophoto maps of user-defined resolution in user boundaries and cuts (I. Zhurkin, 2012).

2) Program Erdas Imagine

The universal software product Erdas Imagine, used in this study for UAV data processing, in order to improve the quality and accuracy of the results. It consolidating remote sensing, photogrammetry, LiDAR analysis, and radar processing into a single product. (Erdas Imagine Brochure, 2012: 4) This is

an easy software Erdas Imagine supporting multiple workflows, including:

- Data conversion
- mosaicking
- Land cover mapping
- LiDAR classification
- Spatial modeling and analysis
- Terrain creation

The capabilities of Erdas Imagine can vary depending on the user's needs at creating the geospatial projects: from Imagine Essentials, through Imagine Advantage, to Imagine Professional. To increase the productivity and increase data processing capabilities, allowing to solve a wide range of tasks related to photogrammetric processing of images, additional specialized

modules are available. Each subsequent package includes the previous one and extends its functionality (I.Zhurkin, 2012). The Erdas software is designed for fast processing of big data, for carrying out deep image analysis and creating 3D images.

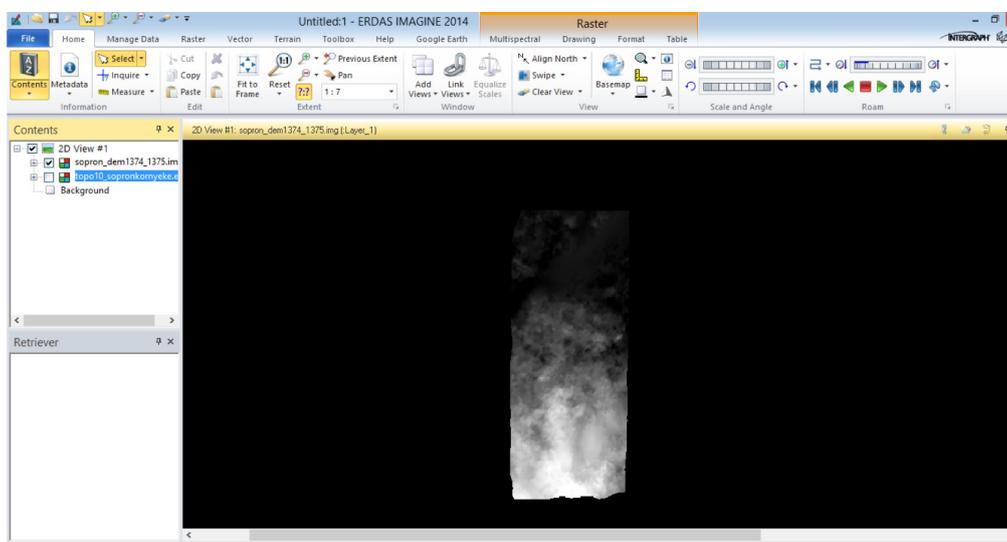


Figure 5 – Fragment of processing Erdas Imagine program

3) Program Fugro Viewer

Another software we chose was the free program Fugro Viewer, which allows users to improve the processing of their geospatial data

(fugro.com). You can get a three-dimensional model, longitudinal profile, orthophoto. Suffice functional program that allows you quickly and efficiently processing the data.

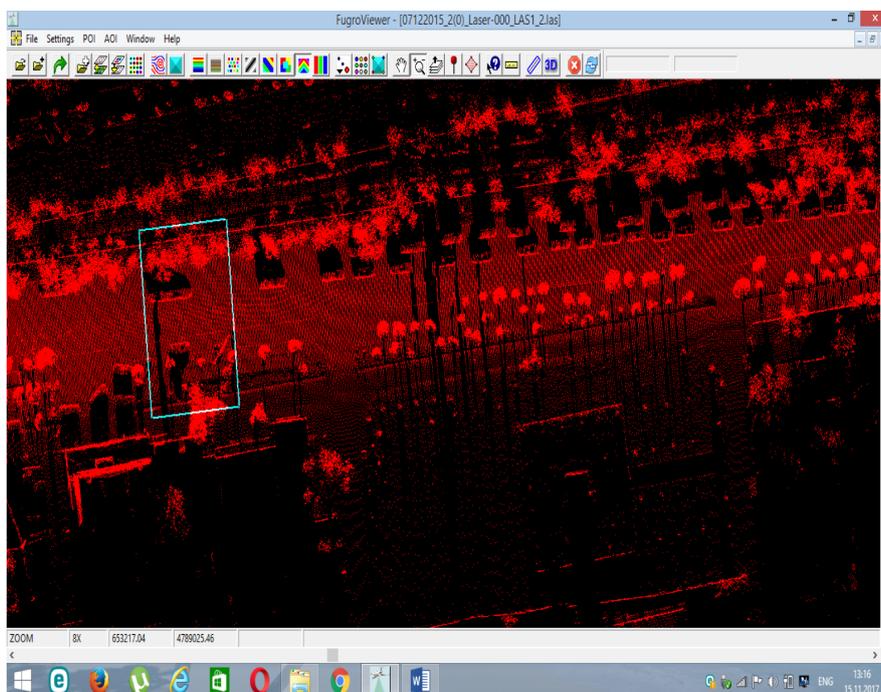


Figure 6 – Fragment of processing FugroViewer program

Results and discussion

The Photogrammetric, geodetic and mobile laser scanning serve to obtain qualitative input data. The necessary accuracy and size of the area of interest are decisive factors for choosing the appropriate method for developing the material. (V.Safar , Z.Smejkal, 2014). This paper carries useful data on how to process the data and which software

parameters should be chosen during MLS or UAV data processing. The study highlights differences in the output DEMs depending on various possibilities of “point cloud” data processing. Nowadays there are many software tools and applications have appeared that offer procedures, scripts and algorithms to process and visualize data (K.Korzeniowska, 2011:271).

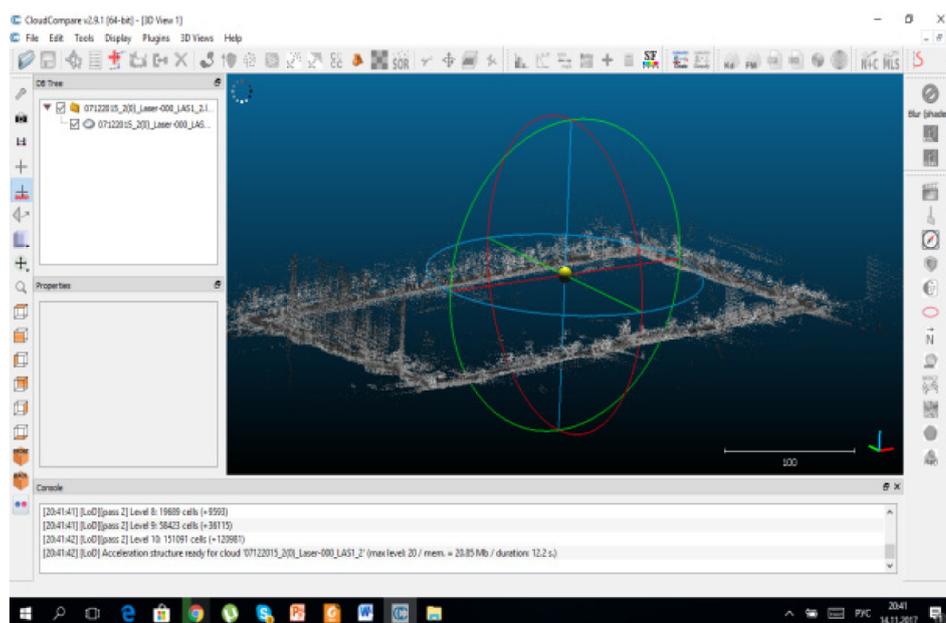


Figure 7 – Program for compare the obtained digital models of Cloud Compare

This set of software and methods for processing contributed to the purpose of this study: comparative analysis of survey results to obtain an estimate of accuracy and improve performance, also various software tools used for data classification, by carefully

studying digital elevation models (DEM), MLS data and UAV data. The work was focused on the most important software tools: both commercial and open source. It should be mentioned, that achieved results depend also on spatial resolution of generated DEMs.

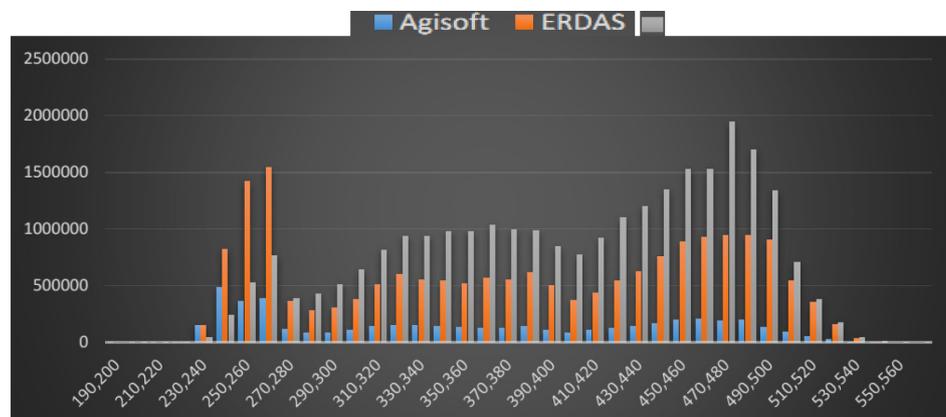


Figure 8 – Comparative evaluation of altitude indicators Digital Elevation Models

We selected Agisoft PhotoScan data processing software as a free soft Fugro Viewer for MLS data processing, as well as the Erdas Imagine program, which was chosen to improve the quality of the processed data from the UAV. Models DEM, created using the analyzed software, were

compared in the program Cloud Compare.

Here in figure 8 it obvious that Erdas and Fugro Viewer are quite similar distributed but AgiSoft is more wide. However if we look to distributed of AgiSoft z histogram it almost repeated the shape of two cloud data.

Table 2 – The results of the comparison of the processing of survey methods

Type of soft	N points	min	max	St.dev	Density point per square unit	Mean	Total area
AgiSoft	4721776	153,48	663,02	118,575	0,40	403,566	11,94
Erdas Imagine	18375866	282,44	581,40	69,4653	2,22 (per s unit)	440,067	8,29
Fugro Viewer for MLS	20966143	254,73	591,54	66,1417	1,44(per s unit)	432,451	14,21

As seen in table 2, Results achieved in this work show that processing in agisoft I Erdas Imagine shows a very big difference, although the original data is the same, performed by the blob, but the Erdas processing is much closer to the mls data. According to our statement, using a more cost-effective UAV method will solve the problem of obtaining more reliable data as a result, giving the same accuracy as MLS, by processing the Erdas data.

Processing in Agisoft and Erdas Imagine shows a very big difference, although the original data is the same, executed by UAV, but the Erdas processing is much closer to the MLS data. According to our statement, using a more cost-effective UAV method will solve the problem of obtaining more reliable data as a result, giving the same accuracy as MLS, by processing the Erdas data.

Conclusion

New requirements on always more superior map sources for needs of road designing call for suitable selection of the acquisition method

(M.Fellendorf,2013). In this paper considered 3 types of survey: tacheometric, UAV method and mobile laser scanning methods of loaded traffic sections of Almaty city road.

According to above the purpose of this work has made a comparative analysis of the results of UAV and MLS data, the processing workflow of survey has been studied and obtained digital terrain models (DTM) which give a more an estimate of accuracy of the investigated terrain. By the goal of our work has been identified the most effective method for creating a DTM, that would allows to reduce the processing time and at the same time leave the reliability and differentiation.

The efficiency of the obtained DTM realized by processing Erdas Imagine of UAV data, which are the same to the results of MLS data. And in comparison with the processing of the Agisoft program exceeds by several times. The application of UAV allows you to quickly and efficiently get information about the research terrain for further design and application of deformations of linear structures.

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