INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr IV/2/2016, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 1347–1361
Komisja Technicznej Infrastruktury Wsi

DOI: http://dx.medra.org/10.14597/infraeco.2016.4.2.099

PRESENTATION OF DIGITAL TERRAIN MODELS OF AGRICULTURAL AREAS USING LIDAR DATA

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Abstract

Digital photogrammetry is one of the intensively developing areas of technical sciences. Increasing participation in the surveying works have digital devices and solutions giving new possibilities in creation of the appropriate map elements and models as well. A particular role to play has the laser scanning technology allowing to present surveyed space or area in the 3D form. Digital Terrain Models for agricultural areas obtained on its basis may be presented in different ways using professional software.

Due to the fact, that in recent years almost the entire Poland was covered with laser scanning, collecting information about the Earth's surface in the form of a cloud of points with high accuracy is a relatively fast process and the results of their elaboration are widely used in many fields.

The paper presents the methods of Digital Terrain Models visualization of agriculture areas for three different objects created on the basis of data derived from airborne laser scanning. The study included agricultural locations – two of them (Strzelce Wielkie and Kamionka Wielka) located in the Malopolskie Voivodship, the third – Mątowy Wielkie in Pomorskie Voivodship, in Żuławy. DTM visualizations were prepared in Macrostation, Terrasolid and Surfer 10 software. For the Mątowy Wielkie object the Digital Surface Model (DSM) was created additionally.

Key words: digital terrain model (DTM), visualization, laser scanning

INTRODUCTION

Nowadays with the progress of technology, we see the advantage of digital methods over conventional methods used so far, in solving any problems relating to spatial objects. Also in land surveying, which is developing rapidly, range of tools used for traditional and alternative methods of measurements evolves from day to day, creating new capabilities and quality of mapping, terrain models and its visualization.

The breakthrough came in the nineties of the twentieth century, when the direct assigning of georeference technology was implemented and the simultaneous development of computers has created perfect conditions for the use of laser measurements in topographic mapping and survey of shapes of objects in the so-called close range. Laser scanning (LIDAR – Light Detection and Ranging) – both airborne and terrestrial – is now firmly established as a method to obtain precise spatial information. Its main task is to generate Digital Terrain Model (DTM), but the airborne scanning (ALS – Aerial Laser Scanning) also proved to be a suitable tool for 3D modeling and landscapes analyses (Kolecka, 2010).

The integration of Terrestrial (TLS) and Airborne (ALS) Laser Scanning despite the differences in their accuracy and resolution, is now very common by the elaboration of spatial objects (Baltsavias *et al.,* 2001; Buckley *et al.,* 2009; Marmol, 2015). Furthermore, the use of scanning and aerial photos helps in solving more complex problems (Marmol *et al.,* 2014). In both methods of laser scanning, fundamental research problems are very similar and related to automatic recording, extraction of objects and spatial modeling (Large and Heritage, 2009). Use of these methods for the spatial visualization is connected with their undeniable advantages, including, inter alia, data acquisition speed and their high density enabling a complete representation of the surface and elimination of errors, measurement of the distance and the ability to integrate with a camera.

Research on the use of terrestrial, mobile and airborne laser scanning to generate digital terrain models and carrying out analyzes on them, have been carried out for many years in Poland (Będkowski *et al.,* 2006; Kwoczyńska, 2013; Bęcek *et al.,* 2015) and worldwide (Baltsavias *et al.,* 2001; Kraus *et al.,* 2006; Liu and Zhang, 2008; Kraus, 2007; Buckley *et al.,* 2009; Large and Heritage, 2009). The obtained results and analysis are presented, inter alia, in studies (Reiss 2002, Shi and Tang 2008, Papasaika and Baltsavias 2009, Mikrut *et al.* 2012, Głowienka *et al.* 2015 and Mikrut *et al.* 2016).

CHARACTERISTICS OF LASER SCANNING METHOD

Measuring the distance to an object in the laser scanning method based on the principle of measurement of the time required for the pulse sent by the emitter to make way to the obstacle, bounce back from it and return to the receiver. The distance that the signal covered from the laser to the object is calculated then. LIDAR technology is analogous to the method of data acquisition using radar. The difference lies in working in a different waveband. In the case of radar these are microwaves, and LIDAR uses the optical range. Nowadays there are many different systems of laser scanning, terrestrial, mobile and airborne, but the idea of measurement remains the same.

In the case of terrestrial scanning the spatial coordinates of the scanner are determined, which determines the coordinates of each point of the cloud on the basis of the recorded angles if incidence of the beam and the calculated distances. Airborne laser scanning uses the platform (aircraft, helicopter, drone), constantly changing its position during the measurement. Determination of the exact coordinates of the optical center of the scanner on board of the platform requires the integration of several cooperating devices. Both the GPS receiver and Inertial Navigation System (INS) or Inertial Measuring Unit – (IMU), recording three Euler angles defining the slope of the platform with the laser (Sagan, 2014) are used.

The system consists of a laser range finder installed on the flying device, data recording receiver, Inertial Navigation System (INS), positioning flight trajectory system (GPS), video camera, flight planning and management system, and ground reference stations GPS and data processing stations. Integration and mutual cooperation of distance measuring system, GPS and INS allow to obtain a sufficiently dense „cloud of points" (spatial points with known coordinates X, Y, Z) to obtain a three-dimensional space representing the surface of the terrain and its cover. The use of video camera recording the scanned area enables during the postprocessing of lidar data simplifying of the „cloud of points" filtering process. In order to remove systematic errors it is recommended to use corrections to the coordinates X, Y, Z, calculated using the control points with at least three times more accurate spatial coordinates eg.: surface of a sports field (Tarek, 2002).

Modern LIDAR systems enable recording a few beams reflected from the object. This feature is particularly appreciated in the case of areas covered with vegetation (forests, city parks), which covers the objects below the trees crowns, such as roofs of buildings, terrain or roads. This feature enables creation of a model of forest cover (on the basis of registration of the subsequent reflections of the laser – a wavelength 1,06μm – from the tree crowns), digital models of buildings in urban areas, and also used more and more often by the energy industry digital models of power lines cables or railway traction.

Comparing laser scanning to the classical methods of aerial photogrammetry it is easy to see a number of advantages of this technology. They result mainly from the activity of the system which means that the obtained image is not dependent on the natural lighting conditions of the terrain, because it generates its own beams. Thanks to this the flight can be performed both during the day and at night, and the ability to scan from the smaller heights solves in part the problem of cloudy sky covering the Earth (fog and heavy rains are still a problem). Images represented by a cloud of points are devoid of shadows, and saved the most commonly in the file format with the extension .LAS, in fact they constitute a stereo model of the entire area. Also surveying field work and later office works associated with the densification of the network are reduced. There is no need to link images and perform aerotriangulation (Dorozhynskyy and Wrona, 2003).

The airborne laser scanning is not yet a perfect solution. The clear disadvantages of this technology are primarily the huge amounts of data, which should be processed in the postprocessing and problems with the representation of the water's surface (laser pulse penetrates their surface), skeletal or discontinuities lines (Borowiecki, 2009).

The quality of the resulting point cloud and its suitability for a particular purpose are affected by many factors. The main factor is the accuracy of determination of the spatial coordinates of points. A study conducted in Stockholm by the Royal Institute of Technology have shown average error of about 0.09m, while during testing the accuracy of the determination of the point mean error of the position was 0.65m at an altitude of 500m, 0.49m for the flight altitude 500m, and 0.70m for the flight altitude 700m.

The factors being important for lidar data processing are: the density of point cloud, divergence of the laser beam, distribution of points and reflection of laser signal. A multiple reflection allows to increase the accuracy and efficient classification of point cloud, as well as to generate a digital model of land cover, creating digital terrain models of forested areas creating digital terrain models of afforested areas or acquisition of data for forestry about the biomass, heights of stands, or diameter of trees crowns. For this purpose scanners capable of recording an infinite number of echoes (full waveform) of a single laser beam are used.

To create a 3D visualization of the object subjected to scanning, data must be properly prepared, grouped in areas homologous with respect to the characteristic properties. This allows to specify the points which do not belong to the land, such as buildings, trees or power lines, which enables creation of digital terrain model or presentation of certain components of its coverage. This is referred to as the classification of point cloud (Sagan, 2014).

To isolate only those points that belong to the respective surface filtration is used. This concept should be understood as a form of (automatic) selection and elimination of points not being part of the modeled surface (Borkowski, 2005). A number of studies developing already elaborated algorithms to filter the topographic surface are carried out, as well as research seeking new solutions to minimize the disadvantages of the previous ones.

The most efficient algorithms are those based on resistant linear prediction, iterative approximation of a respectively selected start surface to measurement data, using mathematical morphology operators (criterion of land slopes) (Borkowski, 2005). The most important and also the most frequently used methods of filtering of data are:

- morphological filters,
- gradient method,
- modeling algorithm of the active surface,
- linear prediction method,
- the method based on the FFT (theory of digital signal processing),
- method using the intensity of the reflections,
- model TIN with the criterion MDL,
- the active model TIN algorithm.

The use of the above algorithms enables the automation of work in postprocessing. The quality of the currently available methods and algorithms for filtering and classification of the lidar data was perfectly included in the words (Borkowski and Jóźków, 2007): The applied algorithms do not give the hundred percent efficiency, the subsequent manual verification and correction of automatic process is therefore necessary. With huge data sets of the laser scanning (up to 10^8 points), each manual process required to carry out involves the substantial prolongation of time and increased development costs. Research centers around the world are developing techniques to support the works related to processing the lidar data, but it is still necessary that the operator of the program takes control and makes adjustments (Piechocka *et al.,* 2004).

In 2003, in the framework of Working Group III /3 „3D reconstruction from airborne laser scanner and InSAR data” of the III ISPRS Commission the researches related to the comparison of the existing methods of automatic laser data filtering were conducted (Sithole and Vosselman, 2003). The main objective of the research was to determine the way the developed algorithms work under certain conditions of the topography and land cover. Also the functioning of filtering algorithms with different densities of test data was examined. These studies revealed the advantages and disadvantages of various methods of laser data filtration. Generally, for a typical, uncomplicated area (gently sloping terrain, buildings of medium size, sparse vegetation, a high percentage of field points) all tested algorithms for filtering worked properly. Alas filtration for complex urban areas or areas with dense vegetation is still a problematic issue and a big challenge (Mikrut *et al.,* 2006).

OBJECTS OF THE ELABORATION

Coverage in recent years of almost the entire Poland with laser scanning, relatively quickly facilitated the collection of information on the Earth’s surface, in the form of point cloud with high accuracy. The results of their processing are widely used in many fields. Data from airborne laser scanning obtained in the framework of the project of the emergency protection system ISOK (Informatics System for the Protection of the Country from extraordinary dangers) were used, among others, in:

- elaboration of risk maps and flood hazard maps,
- monitoring of mass movements (landslides, flows, breaks),
- geological and geomorphological research, modeling of soil water erosion using DTM,
- analysis of changes in the sea shore,
- preparation of acoustic maps,
- identification of obstacles to aviation,
- preparation of planning documents – development plans,
- monitoring of Natura 2000 network areas,
- analysis of the 2D and 3D structure of woody vegetation,
- modeling of forest fire risk,
- measurement and survey of linear objects (roads, pipelines, power lines),
- generating 3D models of buildings,
- analysis of the potential of solar radiation energy and many others.

Currently, the most commonly elaborations performed on the basis of the airborne laser scanning are Digital Terrain Models (DTM) and Digital Surface Models (DSM). LIDAR data are ideal for creating both of these products.

MATERIALS AND METHODS

The aim of the study was to demonstrate the different ways of Digital Terrain Models visualization for the objects of agricultural character using available commercial programs. Processing of point clouds of different densities (6 and 12 points/m^2) derived from airborne laser scanning was performed using the Terrasolid software, wherein the modules TerraScan and TerraModeler were used to visualize DTM. Data export to a grid format also enabled the visualization of the DTM in Surfer 10, where this can be done in different ways. The study was carried out in three agricultural villages (Fig. 1). Two of them located in Małopolskie Voivodeship, but with completely different conditions of topography. They were: Strzelce Wielkie – village with a flat area in the rural district of Brześć District, in Szczurowa municipality, lying on the edge of Sandomierz Basin (Fig. 2a) and municipal village Kamionka Wielka, a typical foothills village belonging to the district of Nowy Sacz (Fig. 2b). The third object was Mątowy Wielkie located in Pomorskie Voivodship, belonging to the „Wielkie Żuławy Malborskie" adjacent to the river Vistula (Fig. 2c). The selection of just such objects was carried out due to their different physiographic conditions, as well as to the plots systems specific for those regions of Poland. LIDAR point clouds for

Kamionka Wielka and Strzelce Wielkie came from the flights carried out in the framework of the project ISOK, were made in standard I (6 points / m^2, Spatial accuracy of the cloud: mean square error for the line: (XY) 0.40-0.50m, accuracy of altitude (H) 0.10-0.15m, the clouds were adjusted and after the initial classification with the RGB attributes. For the village Mątowy Wielkie the cloud was made with a density of 12 points/m^2 because of the flooding risk at this object (neighborhood of the Vistula River).

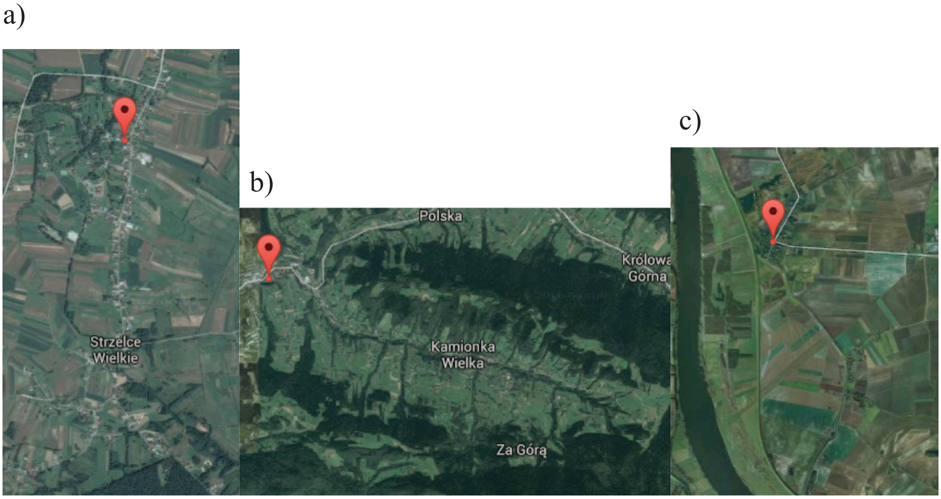
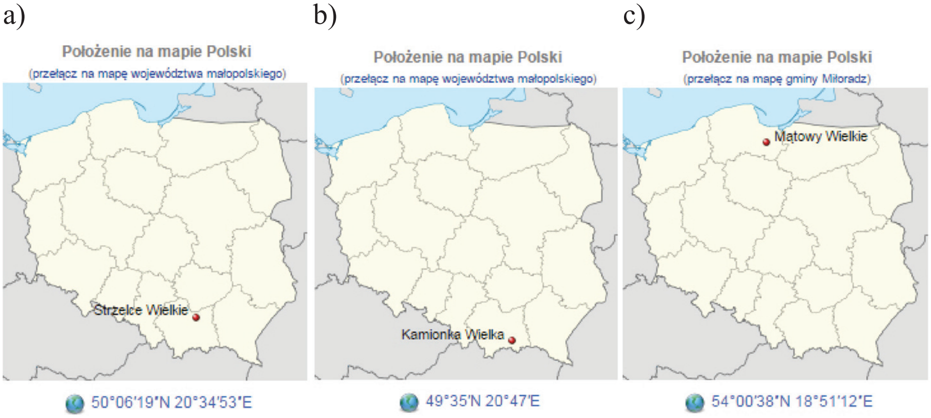


Figure 1. The hybrid map showing land use on objects of research a) Strzelce Wielkie, b) Kamionka Wielka, c) Mątowy Wielkie. Source: https://www.google.com/maps/

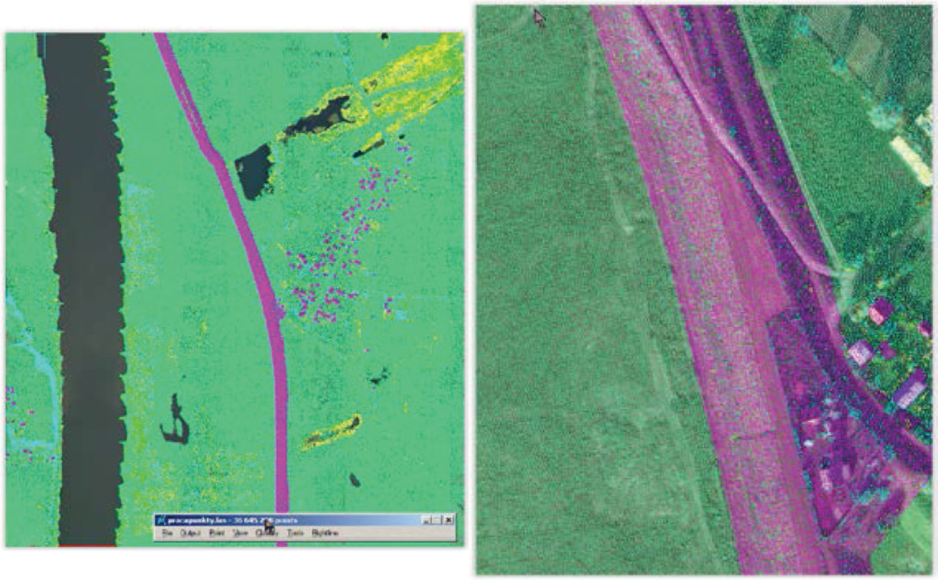


Source: https:// pl.wikipedia.org

Figure 2. Location of test objects on the map of Poland a) Strzelce Wielkie, b) Kamionka Wielka, c) Mątowy Wielkie.

The processing of point clouds took place in the software environment of the Finnish company Terrasolid. For all test items manual corrections, of the point clouds previously classified automatically were made. Particularly the clouds from Żuławy required adjustments, where the automaton incorrectly classified Vistula embankments (Fig.3) and from Strzelce Wielkie, where there were numerous old river beds.

a) b)

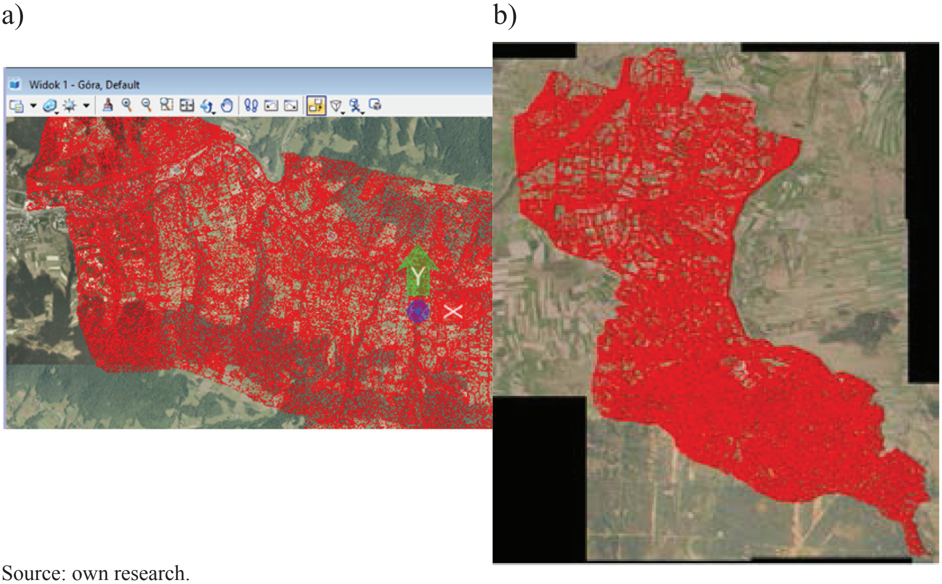


Source: own research.

Figure 3. Flood embankment mistakenly classified as a class of „low points" (violet colour) a/ on the background of the entire cloud, b/ zoomed image.

RESULTS AND DISCUSSION

In most cases, the generation of Digital Terrain Models based on classified point clouds uses the points belonging to the class *Model Keypoints* (Fig. 4), which is created by the points obtained by one of the algorithms operating in the TerraScan module. These are the points of the cloud, which accurately reflect the shape of the terrain. This algorithm is highly efficient. However, in the case of Żuławy, DTM has been generated from all points of the cloud. This is the most accurate possible option, it can be compared to the accuracy of the cloud, which contains a million points to the twenty milion cloud, because it is corresponding relationship (Fig. 5b).

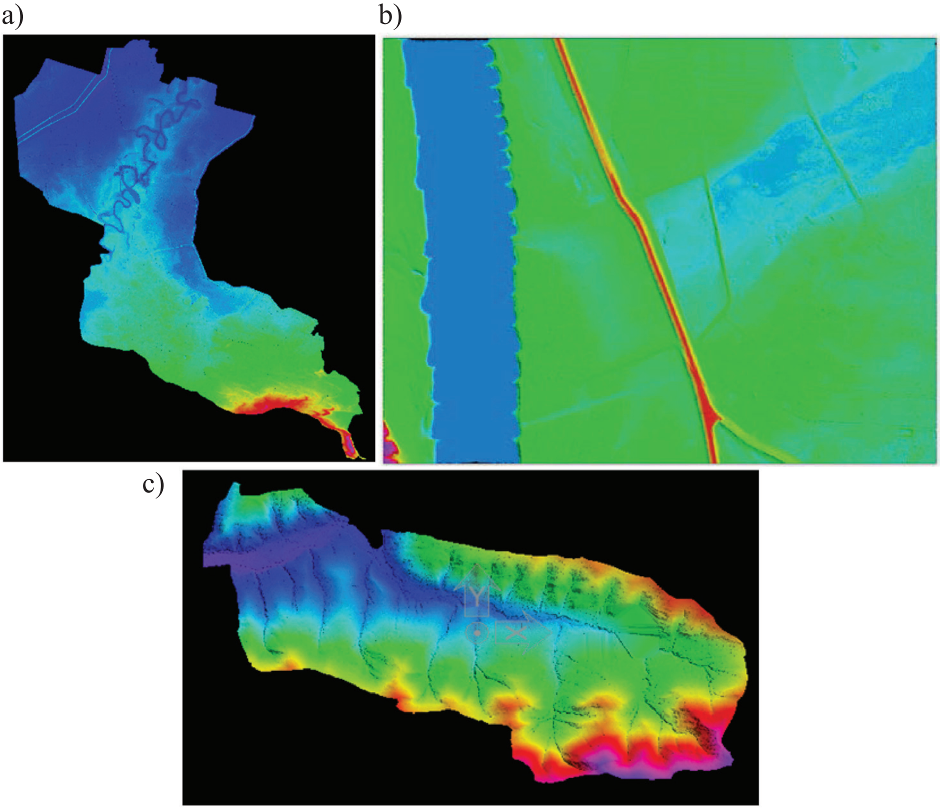


Source: own research.

Figure 4. The points class *Model keypoints* a) Kamionka Wielka, b) Strzelce Wielkie.

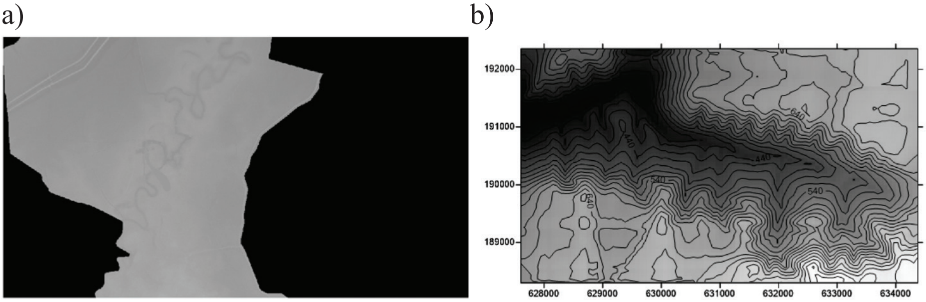
Digital Terrain Models generated by TerraSolid can be visualized in various ways using the functions of TerraScan (GRID model, TIN model, palette of colors, contours, slopes, points with coordinates). The most commonly used visualization of DTM is based on the color palette, assigned depending on the altitude of points (Fig. 5). It is a TIN model built on points of the class *Model Keypoints* with the assigned texture. Some other visualization methods of DTM are possible to obtain with external software, such as, for example Surfer 10. These include: Image Map method, Contour Map, Shaded Relief Map, 3D Wireframe and 3D Surfaces. They were presented for all objects in the figures from number 6 to 9.

DTM visualization in the Surfer software requires the creation of a regular grid of squares GRID and exporting it to the file with the extension default for the program Surfer 10 – grd. To visualize the DTM the mesh size of 5 m was adopted. Examples of visualization show respectively: figure 6 (visualization using Image Map and Contour Map methods), figure 7 (Shaded Relief Map method), figures 8 and 9 (3D Surface and 3D Wireframe methods).



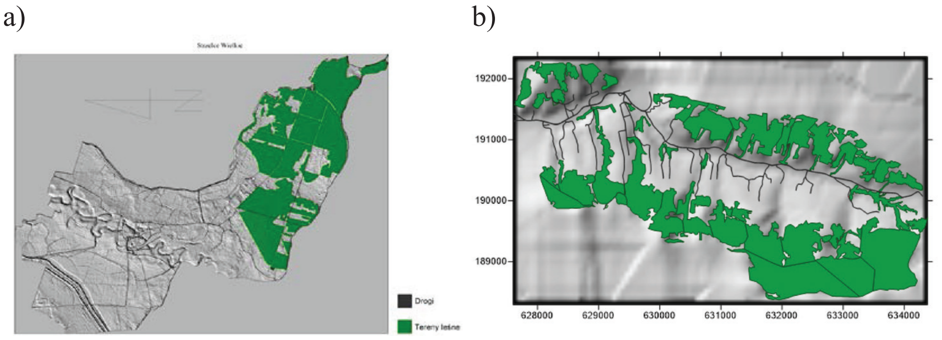
Source: own research.

Figure 5. DTM visualization in TerraScan module using the color palette a) Strzelce Wielkie, b) Mątowy Wielkie, c) Kamionka Wielka.



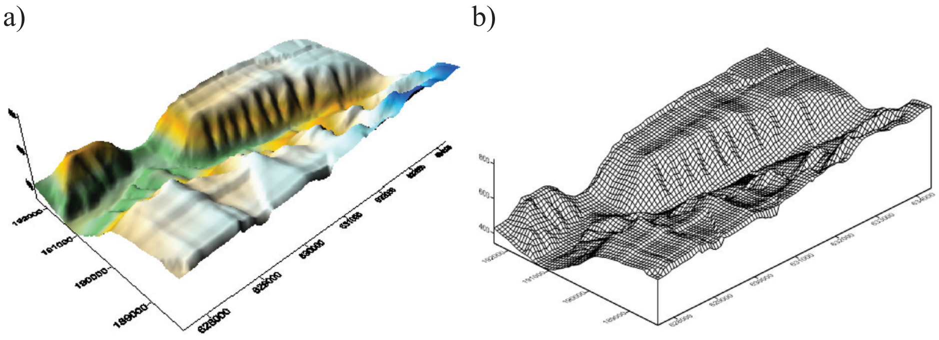
Source: own research.

Figure 6. DTM visualization using methods: a) *Image Map* –Strzelce Wielkie object, b) *Contour Map* combined with *Image Map* –Kamionka Wielka object.



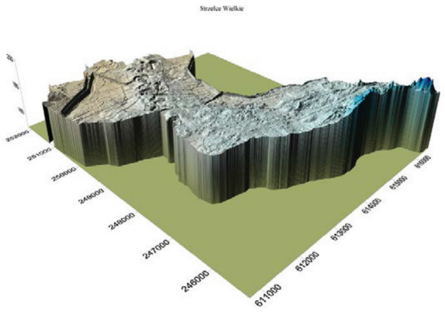
Source: own research.

Figure 7. DTM visualization using *Shaded Relief Map* method
a) Strzelce Wielkie object, b) Kamionka Wielka object.



Source: own research.

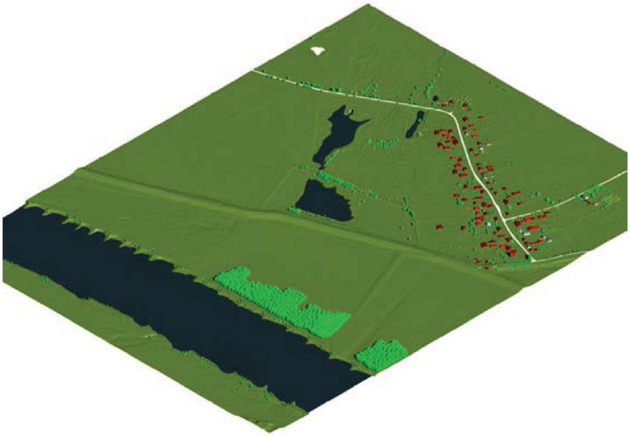
Figure 8. DTM visualization for Kamionka Wielka using following methods:
a) 3D Surface, b) 3D Wireframe.



Source: own research.

Figure 9. DTM visualization of the Strzelce Wielkie object using 3D Surface method

For the Mątowy Wielkie object located in Żuławy, besides the DTM visualization, also in the Terrasolid, DSM – digital surface model was made. Visualization (3D model of the object) shown in Figure 10 was created.



Source: J. Bajor elaboration

Figure 10. DSM for the Mątowy Wielkie object.

CONCLUSION

Currently, the tasks of digital photogrammetry, among others are obtaining Digital Terrain Models (DTM) and Digital Surface Models (DSM). The data obtained from the airborne laser scanning LIDAR are ideal for creating both of these products. Gathering information on the Earth's surface in the form of point cloud with high accuracy is a relatively fast process, and the results of their elaboration are widely used in many fields, eg. in urban planning, agriculture, forestry and civil engineering. Three-dimensional visualization of objects is feasible not only for the individual objects, but also for vast areas, which is successfully used for the presentation of towns and villages for example as virtual tours. The process of elaboration of the lidar data is time consuming, but the specialized software, using complex algorithms brings significant automation of work with point cloud. Visualization of the DTM can be created in different ways and by using more or less complex software. Everything is done according to the needs. Visualizations of the DTM especially for agricultural land help to determine the slopes in a given area, insolation of the terrain and drawing conclusions about soil erosion occurring there in connection with the method of land using. They provide additional information next to the carried out detailed analyzes.

Visualization of Digital Terrain Models is particularly important for floodplains (Mątowy Wielkie object), for which on this basis the flood zones are defined. In mountainous areas (Kamionka Wielka object) DTM visualizations are necessary for the landslide zoning, which implies the need for the change of use of these areas.

REFERENCES

Baltsavias *E., Favey E., Bauder A., Bösch H., Pateraki M* . (2001). *Digital surface modeling by Airborne laser scanning and digital photogrammetry for glacier monitoring.* Photogrammetric Record, 17(98), 243-273.

Bęcek K., Gawronek P., Klapa P., Kwoczyńska B., Matuła P., Michałowska K., Mikrut S., Mitka B., Piech I., Makuch M. (2015). *Modelowanie i wizualizacja danych 3D na podstawie pomiarów fotogrametrycznych i skaningu laserowego.* Rzeszów. Wydawnictwo Wyższej Szkoły Inżynieryjno-Ekonomicznej z siedzibą w Rzeszowie. ISBN 978-83-60507-29-2

Borkowski A. (2005). *Filtracja danych lotniczego skaningu laserowego z wykorzystaniem metody aktywnych powierzchni*. Polskie Towarzystwo Informacji Przestrzennej, Roczniki Geomatyki, Tom III, Zeszyt 4,36-42

Borkowski A., Józków G. (2007). *Ocena poprawności filtracji danych lotniczego skaningu laserowego metodą aktywnych powierzchni.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 17a, 83 – 92.

Borowiecki I. (2009). *Zastosowanie lotniczego skaningu laserowego dla celów opracowania NMT (ocena dokładności pomiarów lidarowych).* Miżwidomczij Naukowo-Technicznij Zyrnik: Geodezija, Kartografija i Aerofotoznimanija. No.71. Lwów. Wydawnictwo Narodowego Uniwersytetu Politechniki Lwowskiej. 211-218.

Buckley S., Schwarz E., Terlaky V., Howell J., Amott B. (2009). *Terrestial Laser Scanning Combined with Photogrammetry for Digital Outcrop Modeling*. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, 38 (B3), 75-80.

Dorozhynskyy O. and Wrona T. (2003). *Podstawy fotogrametrii.* Kraków – Lwów. Wydawnictwo Politechniki Lwowskiej.

Głowienka E., Jankowicz B., Kwoczyńska B., Kuras P., Michałowska K., Mikrut S., Moskal A., Piech I., Strach M. and Sroka J. (2015). *Fotogrametria i skaning laserowy w modelowaniu 3D*. Rzeszów. Wydawnictwo Wyższej Szkoły Inżynieryjno-Ekonomicznej z siedzibą w Rzeszowie. ISBN 978-83-60507-26-1

Kolecka N. (2010). *Wykorzystanie skaningu laserowego do modelowania powierzchni 3D – zastosowania w badaniach środowiska geograficznego.* Numeryczne Modele Terenu w Kartografii. Wrocław. 122-131.

Kraus K., Karel W., Briese C., Mandlburger G. (2006). *Local accuracy measure for digital terrain models.* Photogrammetric Record 2(116), 342–354.

Kraus K. (2007). *Photogrammetry. Geometry from Images and Laser Scans*. Berlin. Walter de Gruyter.

Kwoczyńska B. (2013). *Błędy NMT i NMPT wynikające z automatycznej klasyfikacji chmury punktów pochodzących z lotniczego skaningu laserowego przy zastosowaniu oprogramowania TerrasScan.* Infrastruktura i Ekologia Terenów Wiejskich, PAN Oddział Kraków, No 2/II/2013, 17-30.

Large A.RG. and Heritage G.L. (2009). *Principles of 3D Laser Scanning*. In: Laser Scanning for the Environmental – Sciences. G.L. Heritage, A.R.G. Large (red.). West Sussex: Wiley-Blackwell, 21-34.

Liu X. and Zhang Z. (2008). *LIDAR data reduction for efficient and high quality DEM generation*. In: XXI Congress of the International Society of Photogrammetry and Remote Sensing, 3-11 Jul 2008, Beijing. China.

Marmol U., Mikrut S., Moskal A. (2015). *Integration of Image and Laser Scanning Data Based on Selected Example*, DOI: 10.1515/ipc-2015-0008, https://www.researchgate.net/publication/276544374 date of access 15 april 2016

Mikrut S., Kohut P., Pyka K., Tokarczyk R., Barszcz T. and Uhl T. (2016). *Mobile Laser Scanning Systems for Measuring the Clearance Gauge of Railways: State of Play, Testing and Outlook.* Sensors, 16(5), 683, DOI:10.3390/s16050683

Mikrut S., Pyka K. and Tokarczyk R. (2012). *Systemy do pomiaru skrajni kolejowej – przegląd i tendencje rozwojowe.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 23, 291 – 301, ISBN 978-83-61576-19-8

Mikrut S., Marmol U., Będkowski K. (2006). *Generowanie NMT i NMPT obszarów z pokrywą roślinną na podstawie danych lidarowych.* https://www.researchgate.net/publication/237414029 date of access 15 april 2016

Papasaika H. and Baltsavias E. (2009). *Fusion of LIDAR and Photogrammetric generated Digital Elevation Models*. ISPRS Hannover Workshop 2009, www.isprs.org, date of access 10 may 2016.

Piechocka N., Marmol U., Jachimski J. (2004). *Stereometryczna weryfikacja DTM uzyskanego ze skaningu laserowego.* Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 14, Białobrzegi – Warszawa. 447-459

Reiss P. (2002). *Combination of LIDAR, digital photogrammetry and terrestrial survey to generate high-quality dems.* Geospatial Theory, Processing and Applications. ISPRS Commission IV Symposium 2002, www.isprs.org, date of access 10 may 2016.

Sagan W. (2014). *Opracowanie Numerycznego Modelu Pokrycia Terenu obiektu Brudzew na podstawie danych LIDAR-owych*. Engenering's thesis made in the Department of Agricultural Land Surveying, Cadaster and Photogrammetry under the direction of Dr. Eng. Bogusława Kwoczyńska. University of Agriculture in Krakow 2014

Shi Z. and Tang G. (2008). An Approach from Point Cloud plus Feature Data to GRID DEM. International Archives of the Photogrammetry. Remote Sensing and Spatial Information Sciences. Vol. 37, B3b.

Sithole G. and Vosselman G. (2003). *Report: ISPRS Comparison of Filters*. ISPRS Commission III, Working Group 3, http://www.geo.tudelft.nl/ frs/isprs/filtertest

Tarek Z. (2002). *Skanowanie terenu laserem lotniczym*. Geodeta 12/2002, Warszawa.

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Received: 17.05.2016
Accepted: 07.10.2016