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GENERATING THE OPEN SPACE 3D MODEL BASED ON LiDAR DATA

Aušra Kalantaitė[1], Eimuntas Kazimieras Paršeliūnas[2], Denis Romanovas[3], Dominykas Šlikas[4]

Vilnius Gediminas Technical University,
Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
E-mail: gi@vgtu.lt (corresponding author)

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Abstract. An open space could be defined as a space, which is restricted by a surface, that is generated over the physical Earth's surface, natural and artificial objects, and in which the distances between its objects are less than given critical tolerance. In other words, we have in mind the moving objects of certain dimensions, which could freely move in such an open space.
The technological peculiarities of an open space 3D model generation are analysed. In general, the two sources of data were suggested to apply: the raw LiDAR data and the orthophotomaps. The method for generating an open space surface is presented too.
An open space 3D model of the experimental territory was generated. The data of single orthophotomap on a scale of 1:10000 was applied. LiDAR and orthophotomap data is for the year 2009.

Keywords: LiDAR, orthophotomap, digital surface model, open space model.

1. Introduction

The usage of the LiDAR (Light Detection and Ranging) data is growing up. One of the main motives for its usage is the high speed of data acquisition (Schickler, Thorpe 2001; Žalnierukas, Čypas 2006; Stankevičius 2009). The main scientific field of using the LiDAR data in geodesy and remote sensing is to construct the digital heights models (digital elevation models, digital terrain models, digital surface models, digital relief models) (Arrowsmith 2006; El-Sheimy *et al.* 2005; Yan *et al.* 2012; Sulaiman *et al.* 2010; Susaki 2012; Zhang, Whitman 2005; Meng *et al.* 2010). But the raw LiDAR data are not only geodetic heights, but also the information about other natural and artificial objects on Earth's surface (for example, vegetation, buildings, etc.) (Fowler 2001; Stankevičius 2009).

An open space could be defined as a space, which is restricted by a surface, that is generated over the physical Earth's surface, natural and artificial objects, and in which the distances between its objects are not less than given critical tolerance. In other words, we have in mind the moving objects of certain dimensions, which could freely move (fly) in such an open space. We intend to apply only 2D restrictions caused by moving objects, so, for example, airplane could fly over the bridge only, nor there is a free enough space to fly under it. The open space surface will be closed to the very digital relief model's surface in the agricultural areas and grasslands, therefore it will be over trees in the forests, or over buildings' roofs in the cities. In some sense the open space 3D model is similar, for example, to the Digital Surface Model (DSM) or to the obstacles limitation map of the airport area (Terrain 2011). Therefore, the developers of such maps do not take into account the moving objects' dimensions.

2. Experimental data

In 2008–2010 the LiDAR data were captured for all territory of Lithuania. According to the technical requirements, the density of the points is approximately 4 points in 1 sq. m. This results in a very high resolution data set with a good spatial distribution. The accuracy of any LiDAR data point is not worse than 15 cm in height component, and not worse than 30 cm in plane position (Detalaus … 2007; Lietuvos … 2008; Žalnierukas *et al.* 2009). At the same time the colour orthophotomaps were also made (Fig. 1).

The raw LiDAR data were classified into three groups: Earth's surface data, buildings data and vegetation data. Therefore, for the purpose of developing the open space 3D model, the data was divided into two sets: filtered data set – Earth's surface data, and non-filtered data set – all LiDAR data. The research territory of 1 sq. km was chosen with a total amount of the LiDAR data points of about 1.5 m (Fig. 2).

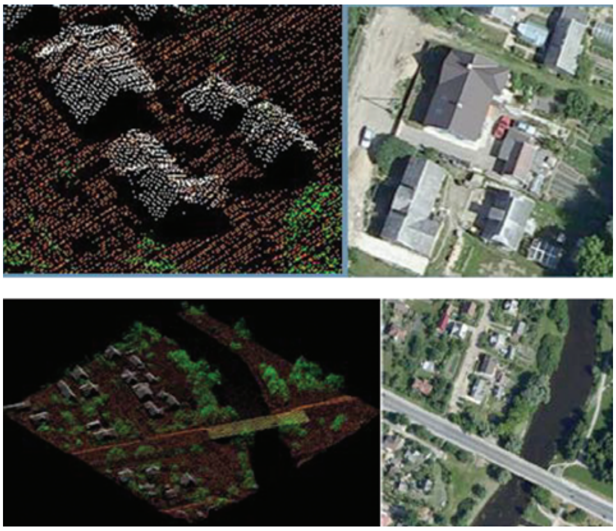
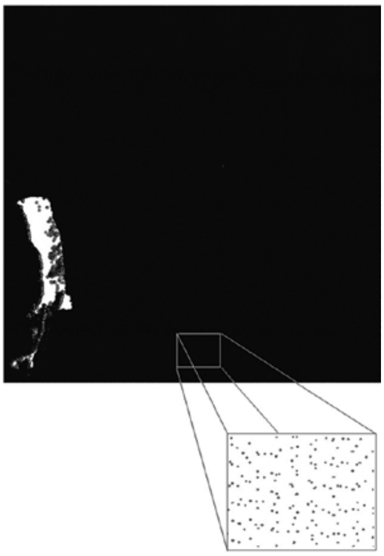


Fig. 1. Fragments of LiDAR data set and orthophotomap

a)



b)

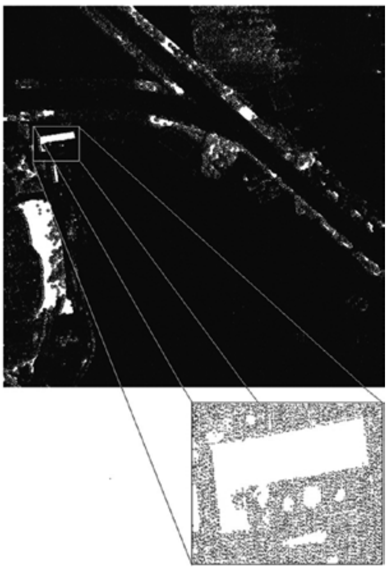


Fig. 2. Graphical views based on LiDAR data sets (a – all points, b – Earth's surface data set)

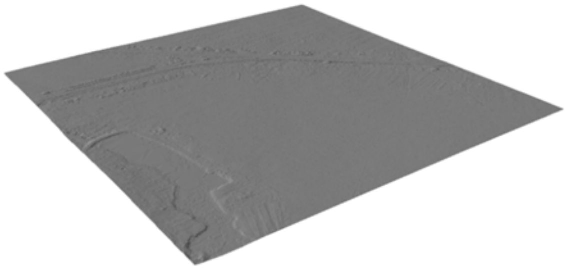
3. Method of the open space 3D model construction

From Figure 2a it can be obviously seen that a density of the points in the area of the water body is much more less than in the other places of the territory. It is even less than it should be according to the technical requirements. In Figure 2b we could see that the LiDAR points of the buildings were eliminated, as well as the points captured from the vegetation.

In the first step, the 3D models based on both data sets were generated. They were expressed by the Triangle Irregular Networks (TIN) (Fig. 3).

In the second step, the 3D model based on the non-filtered data set is combined with the orthophotomap to visualise the territory (Fig. 4).

a)



b)

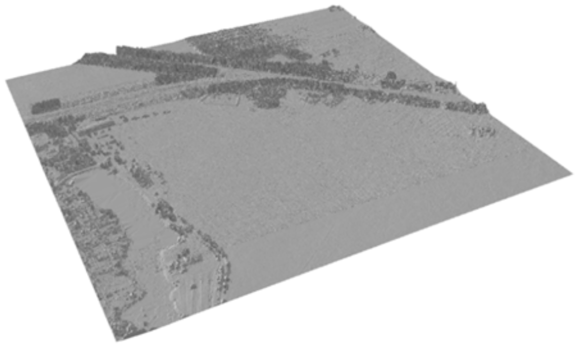


Fig. 3. Graphical views of the 3D models (a – based on filtered data set, b – based on non-filtered data set)

Fig. 4. Graphical view of a combination of the 3D model and orthophotomap

This combination of the 3D model and the orthophotomap will be used for the control of the open space 3D model.

In the third step, we suggest to apply the local interpolation algorithm (Arrowsmith 2006; El-Sheimy *et al.*

2005; Yan *et al.* 2012; Sulaiman *et al.* 2010; Susaki 2012; Zhang, Whitman 2005; Meng *et al.* 2010) the result of which will lead to the generation of the open space 3D model. First of all, the critical dimension *X* of the moving object should be defined (Fig. 5). This dimension will be the cell size of the grid network of the open space 3D model. For example, let it be 10 m. Later on, the LiDAR points are grouped according to the network cells, and in each cell the maximal value of the point's height is retrieved. This maximal height values are assigned to the central points of each cell (Fig. 5).

Also, we should stress that density of the points in the open space 3D model is 1 point in 100 sq. m only (when *X* = 10 m) (Fig. 6).

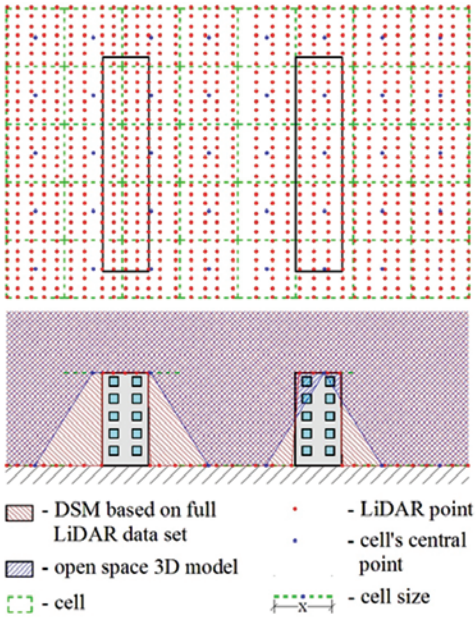


Fig. 5. Graphical interpretation of the method logic

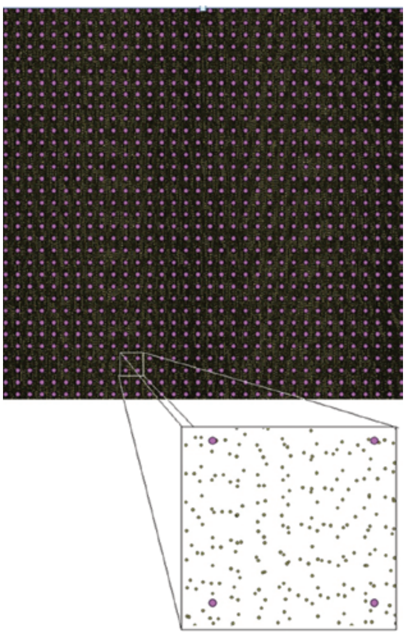


Fig. 6. LiDAR points (black dots) and open space 3D model points (circles in magenta)

Graphical representation of the created open space 3D model surface is shown in Figure 7.

To test the open space 3D model, we could create the surface based on all LiDAR points (LiDAR surface) (Fig. 8).

Now we can subtract the open space 3D model surface from the LiDAR surface in order to receive the surface of two models differences (Fig. 9).

These differences should be with a sign "+". Otherwise the open space 3D model will contain obstacles, what is against its definition.

To analyse in more detail the quality of the open space 3D model, we could create profiles along the created surfaces. For example, in Figures 10 and 11 the two profiles are shown: over the building and over the railroad.

It can be seen that in some places (for example, between points 11 and 12) the obstacles still remain in the open space 3D model. It means that an algorithm of the open space 3D model construction should be improved. It could be done by adding points to the maximal heights values in the corners of each cell of the grid network. It will increase twice the number of the points in the open space 3D model. Therefore the open space 3D model will be free from any obstacles. Also, it should be noted that data on some obstacles like poles, antennas, towers should be included in the LiDAR data set additionally and, probably, manually, because in most cases these obstacles could not be detected by the LiDAR scanning process.

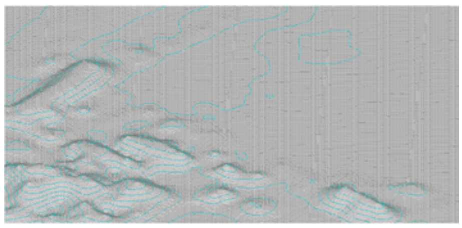


Fig. 7. Isometric view of the open space 3D model surface

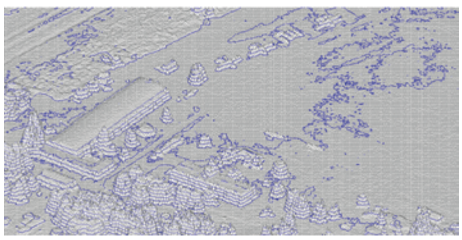


Fig. 8. Isometric view of the LiDAR surface

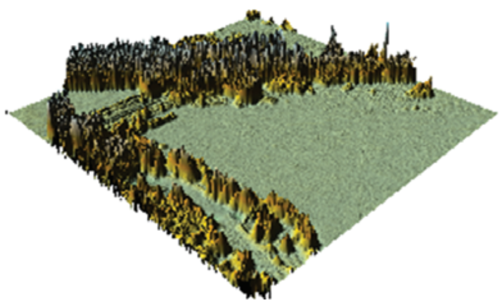


Fig. 9. Isometric view of the surface based on differences

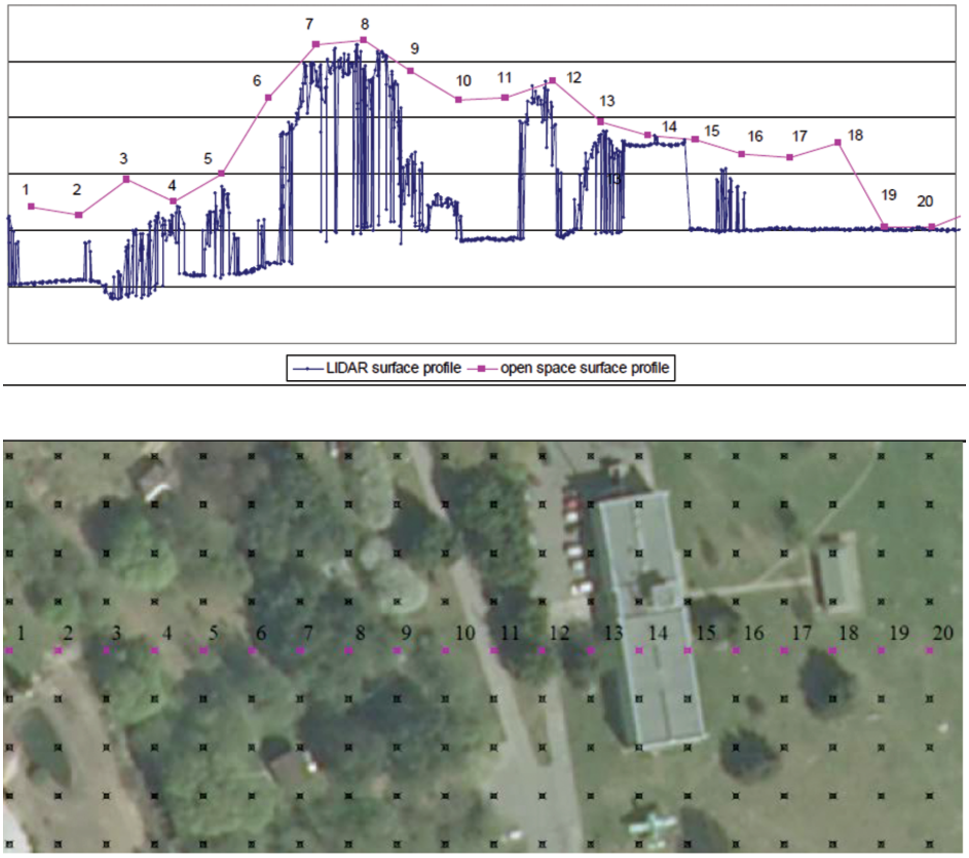


Fig. 10. Graphical view of the profile over the building

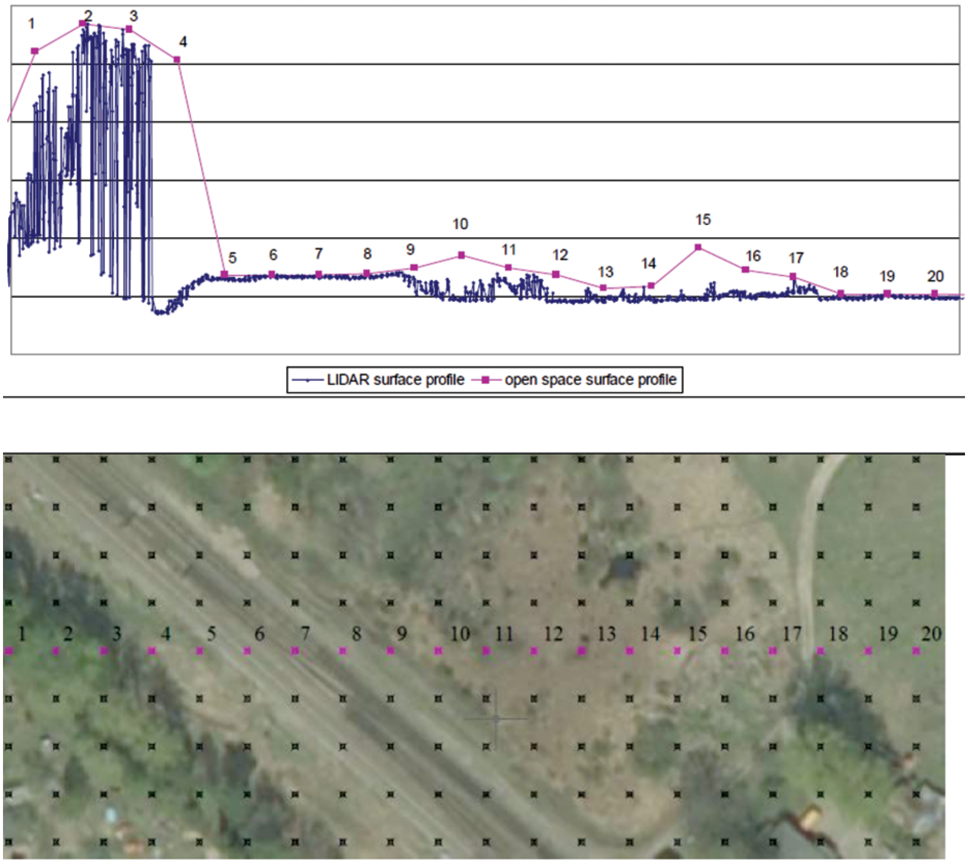


Fig. 11. Graphical view of the profile over the railroad

4. Conclusions

The definition of the open space 3D model was introduced. The LiDAR full data set was suggested to use for the construction of the open space 3D model.

The method for the development of the open space 3D model was presented. The method uses the local interpolation algorithm and the critical dimensions of the moving objects in the open space to create the grid network of the open space 3D model surface.

To verify the correctness of the open space 3D model it was suggested to investigate the differences between LiDAR surface and open space 3D model surface. It is stated that these differences should be with sign "+", otherwise the obstacles will still remain in the open space 3D model.

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Aušra KALANTAITĖ. Head of GIS and cartography division at National Land service under the Ministry of Agriculture Ph + 370 5 239 8446, doctoral student of Vilnius Gediminas Technical University, Ph +370 5 274 4703, e-mail: *gkk@vgtu.lt.*

A graduate of Vilnius Gediminas Technical University (MSc, 1997). Participation in projects: Land Parcel Identification System creation in Lithuania (2002–2003), Land Parcel Identification System and Block Database update in Lithuania (2004–2006).

Research interests: digital mapping, GIS, LiDAR.

Eimuntas Kazimieras PARŠELIŪNAS. Professor, Doctor. Vilnius Gediminas Technical University. Dept of Geodesy and Cadastre, Ph +370 5 274 4703, Fax +370 5 274 4705, e-mail: *eimis@vgtu.lt.*

Doctor (1992). Habilitation procedure in 2008. Author of two educational books and more than 50 scientific papers. Participated in many intern conferences.

Research interests: graphs theory in geodesy, adjustment of geodetic networks, geoinformation systems.

Denis ROMANOVAS. MSc student, Vilnius Gediminas Technical University. GIS programmer at the National Centre of Remote Sensing and Geoinformatics „GIS-Centras", Sėlių g. 66, LT-08109 Vilnius, Lithuania, Ph +370 5 2724 741, Fax +370 5 3737 723, e-mail: *d.romanovas@gis-centras.lt*.

Research interests: GIS analysis and application programming.

Dominykas ŠLIKAS. Doctoral student. Vilnius Gediminas Technical University. Dept of Geodesy and Cadastre, Sauletekio al. 11, LT-10223 Vilnius, Lithuania, Ph +370 5 274 4703, Fax +370 5 274 4705, e-mail: *dominykas.slikas@vgtu.lt.*

MSc at VGTU (2007).

Research interests: calibration of geodetic instruments, engineering geodesy, airborne and terrestrial laser scanning.