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Section: Technologies of Geodesy and Cadastre

On optimization issue to generate the digital open space surface

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Abstract

We proposed the algorithm to generate the digital open space surface model (DOSM), which supplements the Earth's surface (Digital Surface Model – DSM) and the relief surface (Digital Terrain Model – DTM) model group. The open space is characterized as the space, which is restricted by the surface, transient physical surface of the Earth, on the surface of natural and artificial objects and the distances, in which between these irregularities of the surface are not lower than the prescribed tolerances. The digital open space model is slightly different from other models, because it is described by the cell size, defining the minimal possible free space volumes, and it is free from the spatial obstacles also. During generation of the digital open space surface it is necessary to optimize the grid to obtain the wider open space. The goal is to get the minimal sum of the heights of all grid cells. It is suggested to apply algorithm, which implements the iteration process of the grid adjustment along the coordinate axis.

Keywords: Digital Open Space Model; Digital Surface Model; Digital Terrain Model.

1. Introduction

The number of applications of the LiDAR (Light Detection and Ranging) data is growing up. One of the main motive for its usage is the high speed of data acquisition [1–4]. One of the main field of the LiDAR data usage in the geodesy and remote sensing is to construct the digital elevation models [5–8]. 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.) [4, 9]. We would like to proposed the algorithm to generate the open space surface model, which supplements the Earth's surface models group (digital surface model – DSM) and the relief surface (Digital Terrain Model – DTM).

An open space could be defined as a space, which is restricted by a surface, which is generated over the physical Earth‘s surface, natural and artificial objects, and in which the distances between her objects are not less than given critical tolerance. In other words we have in mind the moving objects of the certain dimensions which could freely fly (move) in such open space. We intend to apply only 2D restrictions caused by moving objects, so, for example, airplane could move over the bridge only, nor there is a free enough space to fly under it. The open space surface will be closed to the digital relief model surface in the agriculture areas and grasslands, therefore will be over trees in the forests, or over building's roofs in the cities (Fig. 1).

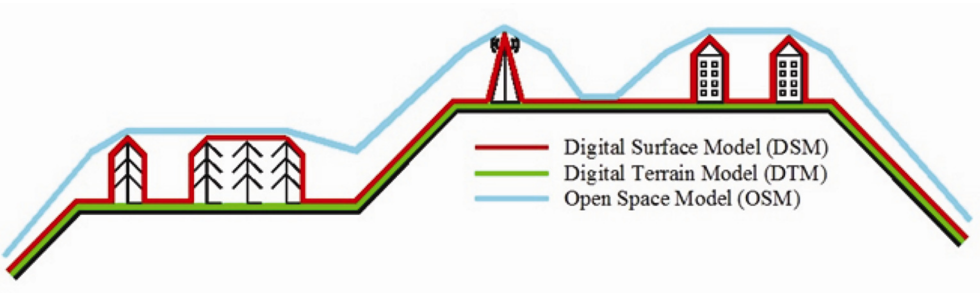

Fig. 1. Surfaces represented by a Digital Surface Model, Digital Terrain Model and Open Space Model

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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 [10]. Therefore, the developers of such maps do not take into account the moving objects dimensions.

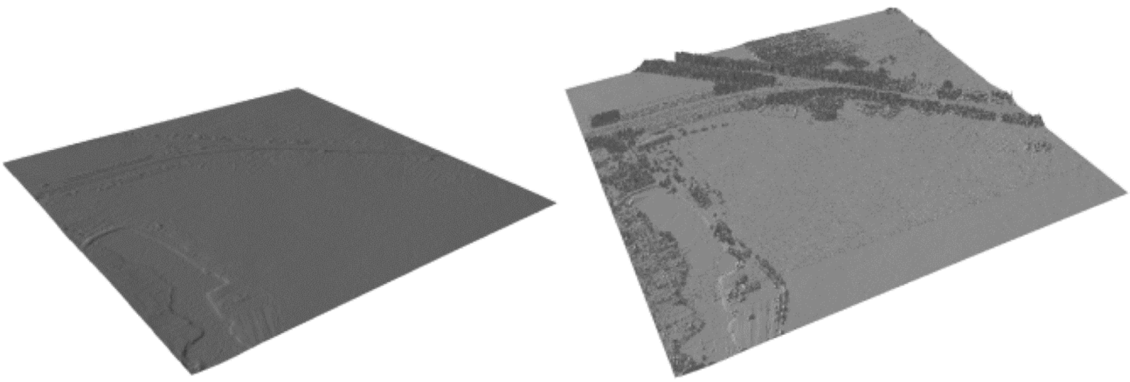
2. Experimental data

In 2008–2010 the LiDAR data were captured for all territory of Lithuania. According to the technical requirements, the density of the points approximately is 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 [11] At the same time the color orthophoto maps were produced also.

LIDAR data could be classified into three groups: land surface data, building data and vegetation data. Experimental data set was divided into two sets: a set of filtered data (land surface data) and unfiltered data set (all data collected by laser scanning method)

3. Method of the open space 3D model construction

In the first step the 3D models based on the both data sets were generated. They were expressed by the Triangle Irregular Networks (TIN) (Fig. 2).



a) b)

Fig. 2. Graphical views of the 3D models (a – based on filtered data set, b – based on non-filtered data set)

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

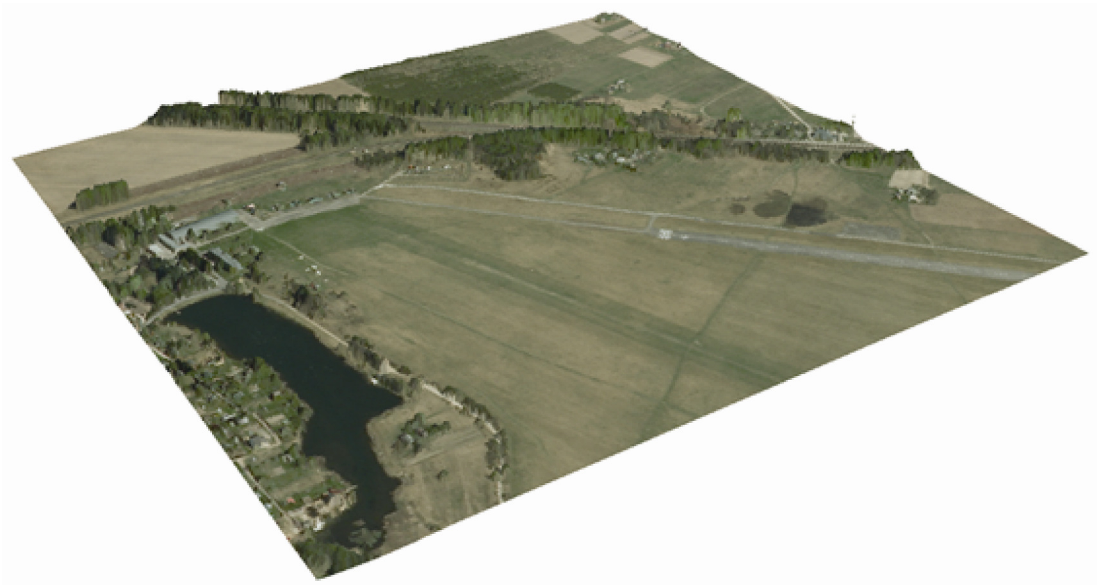


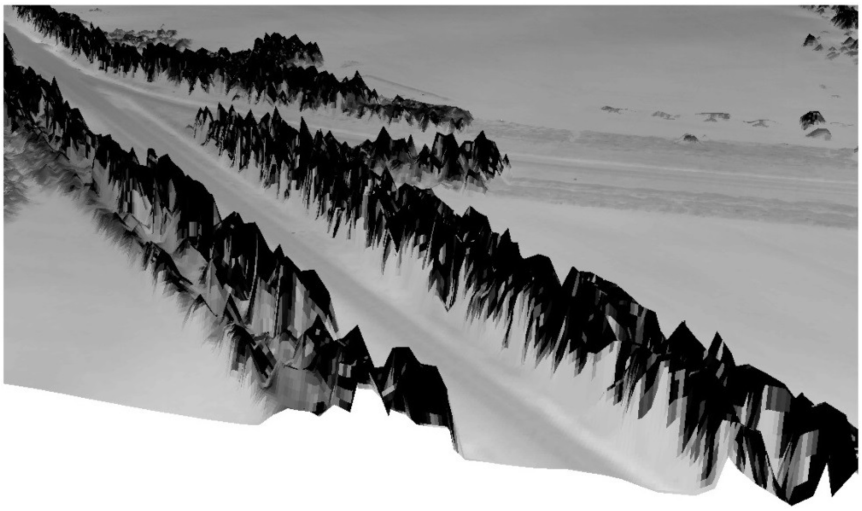
Fig. 3. Graphical view of a combination of the 3D model and orthophoto map

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

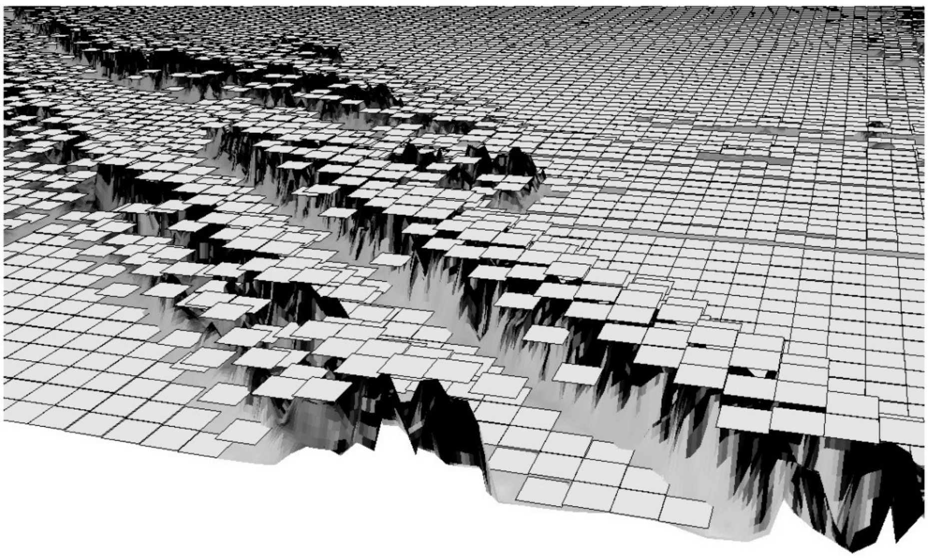
In the third step we suggest to apply the local interpolation algorithm [5–8, 12, 13] (the result of which work will lead to the generation of the open space 3D model. First of all the critical dimension *X* of the moving object should be defined.

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 heights is retrieved. This maximal height values are assigned to the central points of each cell

In addition, network of square cells should be optimized during the construction of the open space model, in a way that an open space is maximized; i.e. sum of the center of the squares heights *H* should have the minimum value of the sum (Fig. 4).



a)



b)

Fig. 4. Diagram of the Earth's surface modelling (a – DSM, b – DOSM)

This is accomplished by sliding squares network in a coordinate axes direction, while the optimal solution is found (Fig. 5).

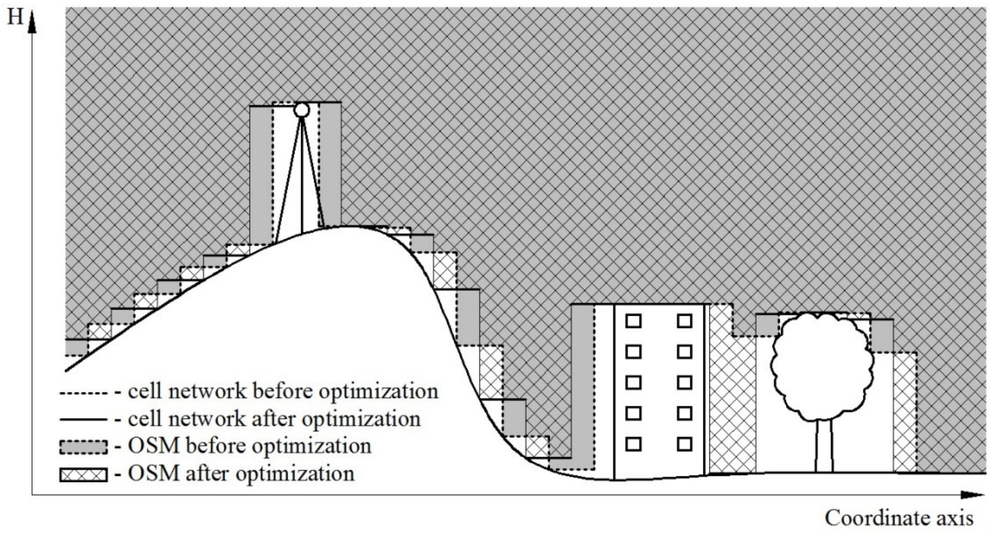


Fig. 5. Diagram of the DOSM grid optimization

For example, if the both (North and East) coordinates shifts are equal to 1 m, the number of produced open space models will be 100.

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).

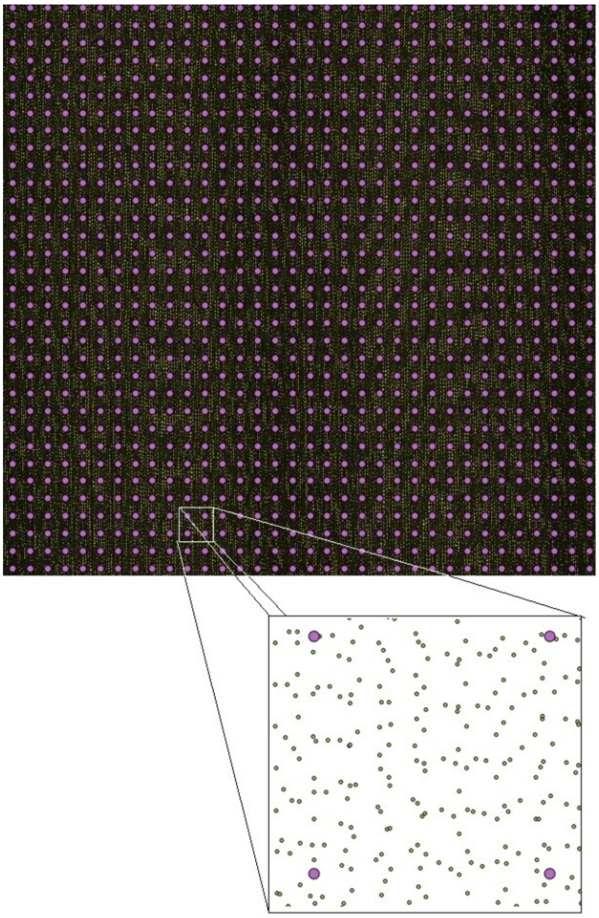


Fig. 6. LiDAR points (black dots) and open space 3D model points (circles in magenta)

In order to analyse more detail the quality of the open space 3D model we could create profiles along the created surfaces. For example, in the Figures 7 and 8 the two profiles are shown: over the building and over the railroad.

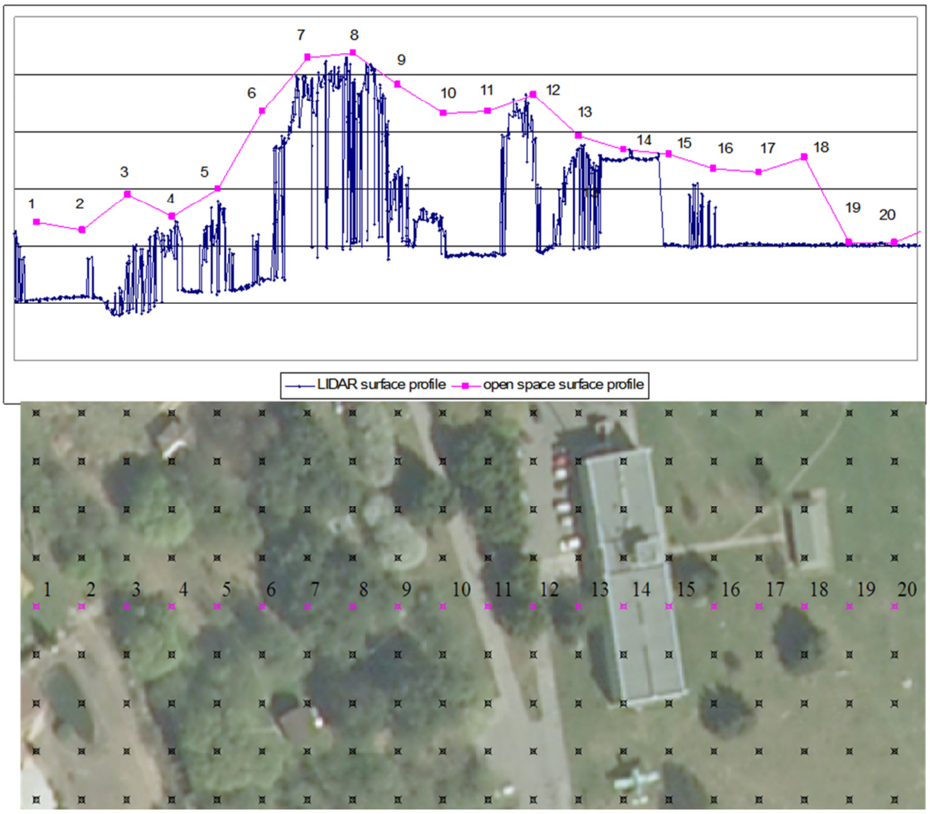


Fig. 7. Graphical view of the profile over the building

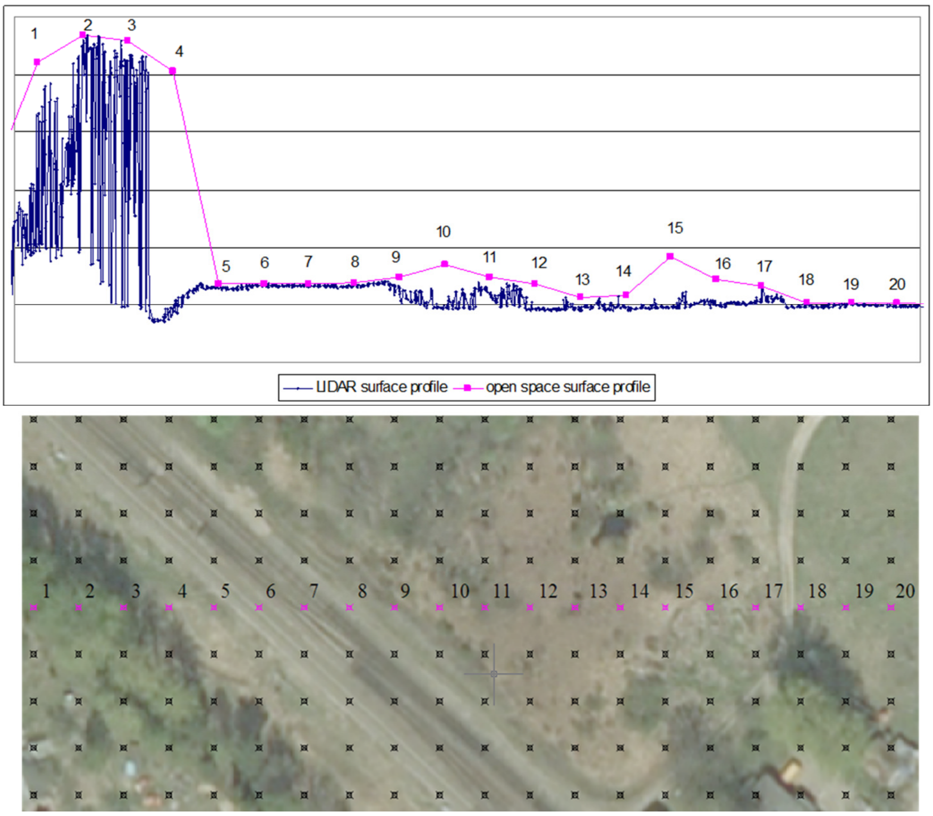


Fig. 8. Graphical view of the profile over the railroad

It is seen, that in some places (for example, between points 11 and 12) the obstacles still remain in the open space 3D model. That mean, that an algorithm of the open space 3D model construction might be improved. It could be done by adding points with the maximal heights values in the middle between the central points of the grid network cells. It will increase by four times the number of the points in the open space 3D model. Therefore the open space 3D model will be free from any obstacles. Also should be noted, that data on some obstacles like poles, antennas, towers should be included in the LiDAR data set additionally and manually, because these obstacles could not be detected by the LiDAR scanning process.

4. Conclusions

1. The concept of open space 3D model has been proposed, thus complimenting the group of the available digital models of the Earth's surface – Digital Surface Model (DSM) and the Digital Terrain Model (DTM). The LiDAR full data set was suggested to use for the construction of the open space 3D model.
2. 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.
3. To verify the correctness of the open space 3D model it was suggested to investigate the differences between LiDAR surface and open space 3D 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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