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THE APPLICATION OF GIS IN SPATIAL PLANNING

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Summary

The article presents the possibilities of using 3D GIS in town planning and urban design, in order to determine the maximum height of the planned development, taking into account the landscape of the modeled area. The increasing speed of the urbanization of valuable natural areas requires strict procedures for determining the parameters of the planned developments, in order to minimise the negative impact of newly designed buildings on the existing landscape. The article presents the procedure for determining the maximum height of newly designed buildings, using the available tools of ArcGIS software. As a result, we have obtained a differential model in the form of a TIN triangle mesh, on the basis of which we are able to determine unequivocally the acceptable height of buildings within the boundary of the given development.

Keywords

point cloud • digital terrain model • 3D spatial analysis • optimal height

1. Introduction

Planning and design constitute cognitive activities, the aim of which is to find such a theory of the optimization of a particular system (e.g. a technical device, an organizational structure, or a spatial structure), which would imply that the system meets accepted criteria of efficiency [Łojewski 1997]. Urban design and planning deals with the analysis of urban structures, based on which planning concepts are developed, as well as urban structures are designed, which Jędrychowski [2007] describes as grouping of objects forming a compositional whole with the surrounding, respectively developed area. As noted by Bielska and Oberski [2014], the process should take into account the natural conditions, including terrain or soil conditions. Spatial planning, as part of urban design, is based on two overarching values of spatial order and sustainable development, which according to Fogel [2013] remain vague, resulting in the practice of inadequate management of space by the local authorities. As noted by the author [Fogel 2013], the essence of proper space management is to determine the optimal land use from the point of view of the municipality. When introducing new developments in the areas, which are subject to restrictions, it is recommended that appropriate procedures should be implemented, in order to prevent or rectify their negative impact on natural conditions. The use of GIS in urban design and town planning can overcome the problems associated with low aesthetic value of building developments, designed and implemented without any consistent regulations regarding the shaping of spatial forms, or developing new building projects in open areas of high natural or cultural value [Fogel 2013]. At the same time, as noted by Jędrychowski [2007], regulations of the law do not indicate sufficiently effective ways of processing spatial data, that would include GIS systems. The lack of obligation to apply analytical techniques during the preparation of planning documents affects the prevalence of their use, which directly translates into the quality of these studies.

Visualization of an investment project in natural surroundings makes it possible to select the most favourable version of spatial development, which is particularly useful at the stage of decision-making on the shape of space for the future, and filling that space with man-made objects [Hełdak et al. 2013]. According to Mitka and Szelest [2012], three-dimensional techniques have been present in the practice of architectural design and urban planning for over 20 years and they have many advantages, including supporting the decisions about landscaping and facilitating the search for architectural forms for newly-introduced objects. As noted by Jędrychowski [2007], one of the basic parameters in urban design is the permissible height of the planned building. This parameter is defined in the MPZP (Polish abbreviation for the Zoning Document, or Development Plan) and in the WZiZT (Polish abbreviation for the Decision on the Conditions for Construction and Land Development), and they can be accurately verified on the basis of the Digital Terrain Model (DTM), which – according to Bielska and Oberski [2014] – is one of the most commonly used sources of data about terrain. The DTM introduces a third dimension to the design, which greatly facilitates the design decisions made for areas with varied terrain, particularly in terms of volume or height of newly designed buildings [Mitka and Szelest 2012]. A valuable source of data for creating an accurate DTM is aerial laser scanning, which produces a cloud of points that can be imported into GIS systems. Based on the practices of the Office of Spatial Planning and Development of the City of Kraków, it is stated that the aforementioned data is also a valuable material for creating models of architectural compounds. Based on the developed derivatives, it is possible to perform visibility analyses, in relation to any location, taking into account the proposed (planned) facilities [Jędrychowski, 2007]. In addition, according to Mitka and Szelest [2012], modern IT tools allow the integration of spatial data from different sources, which is particularly important in the development of zoning concept plans, bringing the perspectives of landscape features, topography, and natural conditions into the assessment equation.

The paper presents the method of determining the maximum allowable height of newly designed buildings, planned for implementation on the mountainside, located in the area of particularly valuable natural features. It has been assumed that the proposed buildings cannot rise above the existing line of the horizon as seen from the foot of the mountain, in other words, along the line of sight. Determination of the maximum allowable height of buildings is done using the analytical tools of the *ArcScene* software, as well as the cloud of points from airborne laser scanning.

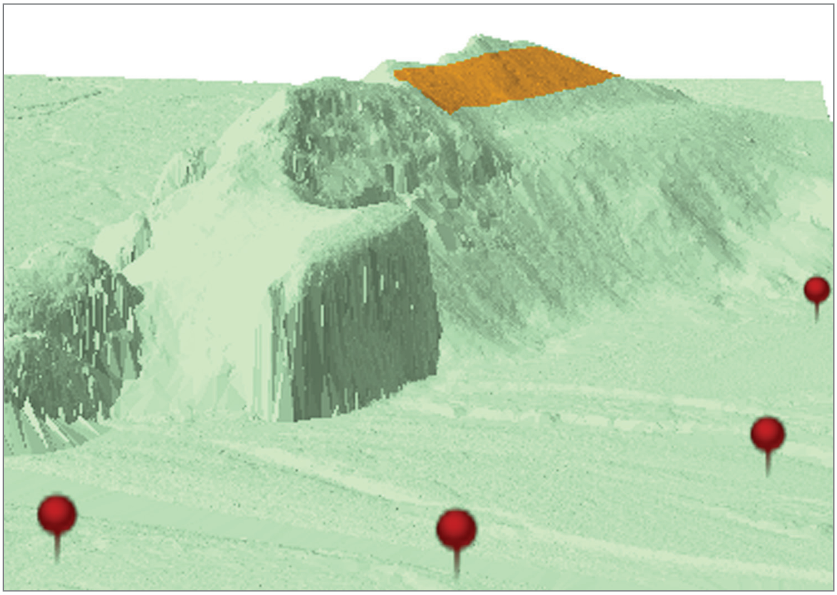
2. Materials and methods

The present study applies a point cloud resulting from the airborne laser scanning, made available by the Polish Central Documentation Centre of Geodesy and Cartography (Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej, or CODGiK for short). For the area of research, point cloud it is made available in standard I (4 points pew sq. m) sufficient to create a digital terrain model, in which the error calculation of the height is no greater than 0.25 m. The data file was acquired from CODGiK, covering the area of approx. 1 sq. km. For a more optimal processing of data, it was necessary to limit the point cloud to the research area, which operation was performed using the *Terrasolid* software. Subsequently, the cloud of points showing only the studied area was imported to the *ArcScene* software, as a *Las Dataset*. The point cloud obtained from CODGiK has been classified in accordance with the Regulation of the Polish Minister of Internal Affairs and Administration of 3 November 2011 on the databases of aerial and satellite imagery as well as orthophotomaps and numerical terrain models [Rozporządzenie... 2011], which distinguishes seven classes of points:

1) representing low vegetation, to a height of 0.40 m,
2) representing average vegetation, with a height between 0.40 m to 2.00 m,
3) representing high vegetation, with a height over 2.00 m,
4) representing buildings and structures,
5) representing areas of water,
6) located on the ground,
7) unclassified.

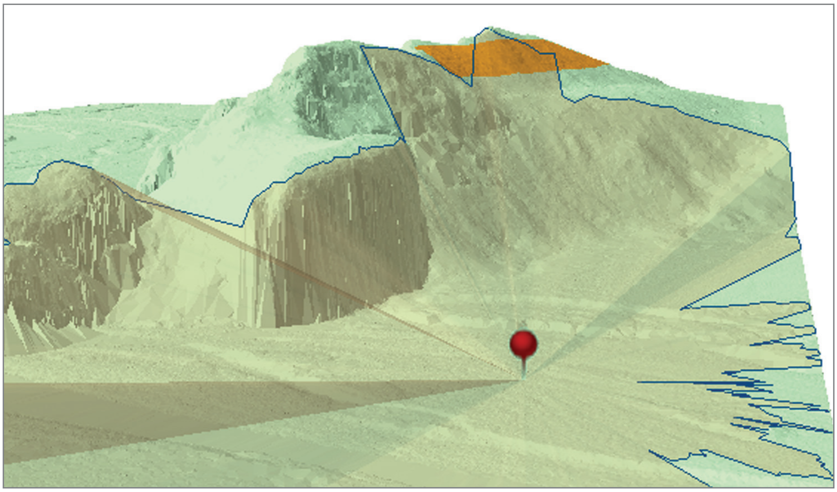
Using the *Make LAS Dataset Layer* function of the *ArcGIS* software, only those points were selected from the complete dataset, which represented the *ground* layer. In the next step, based on the selected points, a digital terrain model was created in the form of a TIN (*Triangulated Irregular Network*). Subsequently, within the rendered area, 4 observation points were set, with reference to which the maximum height of the planned buildings was calculated within the border of the planned investment (Figure 1).

In order to determine the skyline as seen from any observation point, we have used the *ArcGIS Skyline* function. The input data for this function include: the layer of observation points stored in a *shapefile* format, and the Digital Terrain Model saved in a TIN format. In addition, it is possible to define the angles within the border, where the skyline will be designated. As a result, a skyline for all observation points was obtained, in the format of a 3D line, saved in the *shapefile*. Then, based on the skyline created, skyline barriers were obtained (*skyline barrier* function) in the form of planes extending from the observation point to the skyline, corresponding to the appropriate observation point. Skyline barrier constitutes a "roof", above which the newly designed objects would change the course of the skyline. A sample skyline for one of the observation points is shown in Figure 2.



Source: authors' study

Fig. 1. Distribution of observation points within the studied area, and the marked land covered by the planned investment



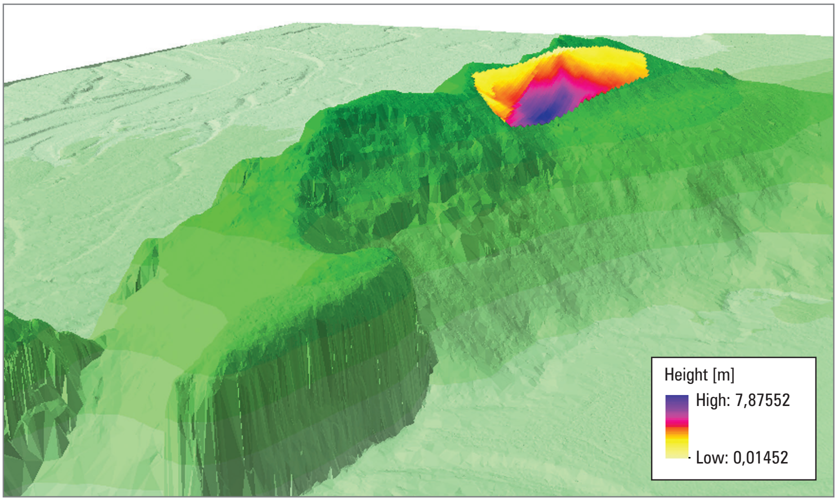
Source: authors' study

Fig. 2. Skyline and skyline barrier for a selected observation point

In the next step, within an area designated for the construction project, points were generated using the *Create Random Points* function, which have been located randomly within the limits of that planned investment. The *Create Random Points* function lets you define the number of points, which in this case was set at 2,000 points, providing a dense coverage of the investment area with random points. Random points are saved in a *shapefile* and they do not have a defined height. One method for changing the amount of points is to change the base layer (*base heights*) in respect to a particular ground surface (*elevation from surface*). After defining the correct *base heights* for random points, the properties were set to *extrude* function, resulting in sections of 500 m in length, passing through all the random points. The *extrude* function only changes the manner of data display, therefore a temporary layer of the line had to be exported to a separate *shapefile* layer. The conversion of a temporary layer into the "random lines" *shapefile* layer was conducted using the *Layer 3D to feature Class* function. Subsequently, intersections were determined of the "random lines" layer with the layer containing the skyline barrier (*3D Intersect line with Multipatch*), and thus a new *shapefile* layer was created, namely the "points of intersection". Based on the latter, the digital terrain model was created in TIN format.

3. Results

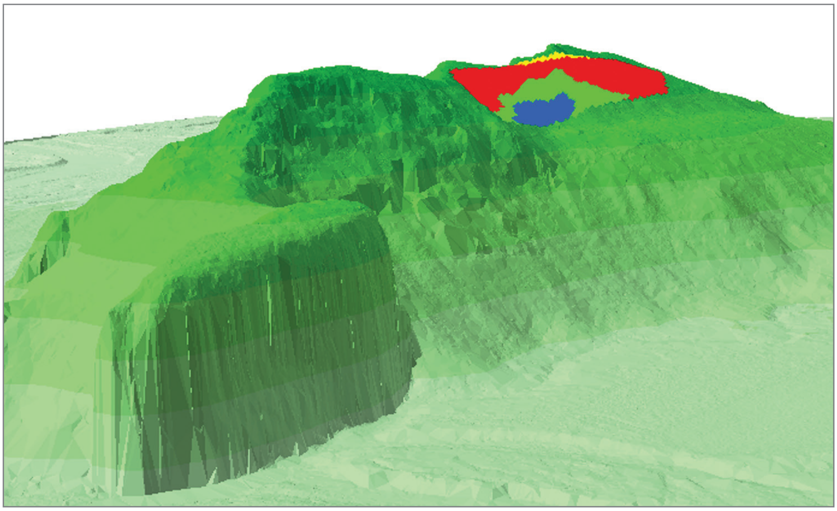
On the basis of the input data: the digital terrain model of the studied area, as well as the digital terrain model created within the limits of the planned investment, a Differential Model was developed, specifying the maximum permissible height of the planned buildings within the area of the investment project (Figure 3).



Source: authors' study

Fig. 3. Differential Model for the area of the investment project

Maximum permissible height was calculated based on the assumption that the newly designed buildings can not rise above the current skyline, as seen from selected observation points, located at the foot of the mountain. The analysis concludes that the maximum building height is 7.88 m, pertaining to areas located in the south-western part of the investment. On the basis of the differential model saved in the format of a raster with a resolution of 1 m, the area was calculated for four classes of height. The division into four classes was made on the basis of the method of equal intervals, wherein the width of the class is the difference between the maximum value and the minimum value, divided by the number of classes. Thus determined height classification is presented in Figure 4, and the calculated areas are given in Table 1. The total area of he investment project is 2,573 sq. m, of which 67% is land designated for development with a maximum height of 3.94 m. Based on the results obtained, it is concluded that the permissible building height enables the realization of the investment project in terms of land development, without adverse interference with the natural landscape.



Source: authors' study

Fig. 4. Height classes for the area covered by the investment project

Table 1. Areas calculated for respective classes of height

Class no.	Height ranges [m]		Area [m^2]
1	0,01452	1,97977	70
2	1,97977	3,94502	1642
3	3,94502	5,91027	589
4	5,91027	7,87552	272
Total			2573

Source: authors' study

5. Conclusions

Spatial planning and urban design are processes in which we need to balance the social and economic interests with respecting spatial order and taking particular care to preserve the natural landscape. Taking into account the many factors in the process of urban design is a challenge, therefore we must use such tools as will provide us with adequate support: both at the design stage, and in the decision-making phase. Among these tools are the GIS systems, which offer a possibility to perform spatial analyses based on three-dimensional data. Based on data from airborne laser scanning, it is possible to build an accurate digital terrain model, which should serve as a starting point and base material for all design work. Taking into account the existing terrain, the assumptions of local zoning plans, as well as the requirements defined at the preliminary design stage, it is possible to simulate the visibility of selected observation points. On that basis, we are able to formulate zoning guidelines for the area, including in particular the maximum permissible height of the planned facilities. The tools offered by the GIS systems substantially exceed the design capabilities based on two-dimensional analogue data, therefore it is recommended that they should be used in everyday practice of every urban planner.

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