http://dx.doi.org/10.15576/GLL/2015.2.55

GLL

Geomatics, Landmanagement and Landscape No. 2 • 2015, 55–61

DIGITAL TERRAIN MODEL AS A BASIS FOR DETERMINING THE FLOODLAND OF THE PRĄDNIK RIVER

Urszula Litwin, Izabela Piech, Dawid Rakowski

Summary

The modern technology gives us the possibility to make a Digital Terrain Model, which is more and more frequently used in various scientific fields. Localizing the floodland on the basis of Digital Terrain Model provides an insight into the reality and is relatively quick.

On the basis of the materials from photogrammetric flight the Digital Terrain Model was prepared, which was measured at the digital station "Delta". The model has been supplemented by elements of land cover, that is meadows and pastures, built-up areas, roads, escarpments, forests and waters. By using the software Surfer a spatial (3-D) model of a studied area has been created. The floodland of the Prądnik river, when the water level is higher by 2 and 5 meters, have also been visualised.

Keywords

Digital Terrain Model • orientation images • flood zone

1. Introduction

The idea of a Digital Terrain Model was developed in the late 1850s, and the first use of the term is attributed to two American engineers of Massachusetts Institute of Technology. According to them DTM is a simple statistical representation of the Earth's surface consisting of large number of points with known terrain elevation coordinates *X*, *Y*, *Z*. The current definition of DTM does not differ much from that of the American scientists, but was adjusted to modern technology and reads as follows: "Digital Terrain Model is a digital, point-based representation of a topographic elevation together with an interpolation algorithm that enables reconstruction of its shape in a given area" [Kurczyński and Preuss 2011]. Usually a DTM model is created by means of regularly or irregularly distributed points on the earth's surface, which is supplemented by points describing specific, morphological forms of terrain. In order to construct comprehensive and useful DTM it is necessary to maintain topological relations between the measured elements and approximate model of reference surface. The surface of the Earth has infinite number of points representing it, and so the sampling method, defining the model of the surface created must include special points, such as points of discontinuity. A specific model of the surface is related to a specific sampling model. Three commonly used methods of representing the Earth's surface can be singled out: contour maps, rectangular mesh (grid) and triangulated irregular network (TIN) [El-Sheimy et al. 2005]. Contour maps with their isolines and known intervals between them are probably the most popular form of terrain spatial representation. A good example of this method are contour maps of different scales. The accuracy of these maps depends largely on the base on which the measurements are carried out. Maps created directly from aerial photographs and then printed on special plotters are characterized by higher accuracy than maps repeatedly processed. If contour maps are generated from point measurements the position of such an isoline must be interpolated. The grid is used by default and topographically the most simple relation of measured points. The density of points used by regular grid must reflect the complexity of terrain height differences, and hence excessive number of measured points is required that would represent the land at an adequate level of accuracy. The grid cells must be evenly distributed in the whole area, and their size depends on the diversity of the terrain forms. Using the structure one needs to remember that relatively large cells of a regular grid do not determine the elevation of points located in their middle, and therefore it is recommended to be used in less diversified terrains.

The accuracy of height determining in DTM is an average error of height interpolated from already generated DTM.

This error is determined by:

- errors of measurements data,
- the size of the cell generated for terrain surface representation,
- lay of the land diversity.

2. The basic notions regarding farmlands and flood risk areas

According to the Ordinance of the Minister of Regional Development and Construction of 29 of March 2001 on land and property register, farmlands can be generally divided into: agricultural lands, forest lands, wooded lands and bushlands, built-up and urbanized areas, lands under water, orchards of size below 0.1 ha and other lands smaller than 1 ha not included in the register. The first ones can be divided into: "arable lands, orchards, permanent grasslands, permanent pastures, built-up arable lands, lands under ponds and ditches. Forest lands and wooded lands and bushlands can be in turn divided into: forests and wooded lands and bushlands. The built-up and urbanized areas are divided into: residential areas, recreational and leisure areas, mining lands and transportation areas". Arable lands include lands cultivated regularly by machines, used for production purposes, lands used for growing wicker, hop, nurseries of ornamental trees and fallow lands. Orchards: lands larger than 0.1 ha planted with fruit trees and shrubs, fruit trees nurseries and vineyards. Permanent grasslands are in general lands covered with perennial vegetation, e.g. with grass, legumes or herbs, systematically mowed.

Permanent pastures, like grasslands, are covered with perennial vegetation, with the difference that they are not mowed, but grazed. Agricultural built-up areas include lands with residential buildings and other buildings used in agricultural production with some exceptions. Lands under ponds are the lands under water reservoirs, used to farming and keeping fish (exceptions: lakes and dams). Ditches are lands covered by drainage ditches [Rozporządzenie Ministra... 2001]. The flood risk areas are lands within the scope of water surges and are mapped out on historical data or theoretical research, which determine the probability of flood and local flooding in a given area. There are direct and potential risk areas. The former one are the areas directly adjacent to rivers or watercourses and areas in a direct vicinity of floodbanks whose crowns can be overflowed with water. The potential risk areas are exposed to destructive activity of waters in case of a floodbank's break or its significant damage. The maps of flood risk areas enable the analysis of the flood threat and make it easier for local authorities to take decision that minimize the negative consequences of floods. To make a flood risk map one need first to collect historical data with maximal surge level of rivers or watercourses. Then the coordinates of water surface need to be determined in order to obtain its profile for a given flow. The boundary of a flood area is marked as an intersection of a water surface profile for a given flow and DTM obtained by photogrammetric methods. The obtained areas can be divided into direct and potential risk areas. On the basis of raster maps, geodesic profiles and the knowledge on hydrology, the final maps of flood risk are created [Drożdżal 2006].

3. The object of the study

The object of the study was a part of the Zielonki commune, located at the basin of Białucha and Garliczka rivers. The commune belongs to the Małopolskie voivodeship, Kraków district, in the direct vicinity of administrative borders of the city of Kraków. Due to attractive location of the area, large number of built-up areas were noted in the study. The difficulty level of study could be determined as moderate.

The material used to make DTM were the aerial photos taken by analogue camera RC20_13166, at a scale 1 : 13 000. The photos were obtained from The Marshall Office in Kraków. They were received in a digital form (with.tif extension) after prior scanning on a special photogrammetric scanner.

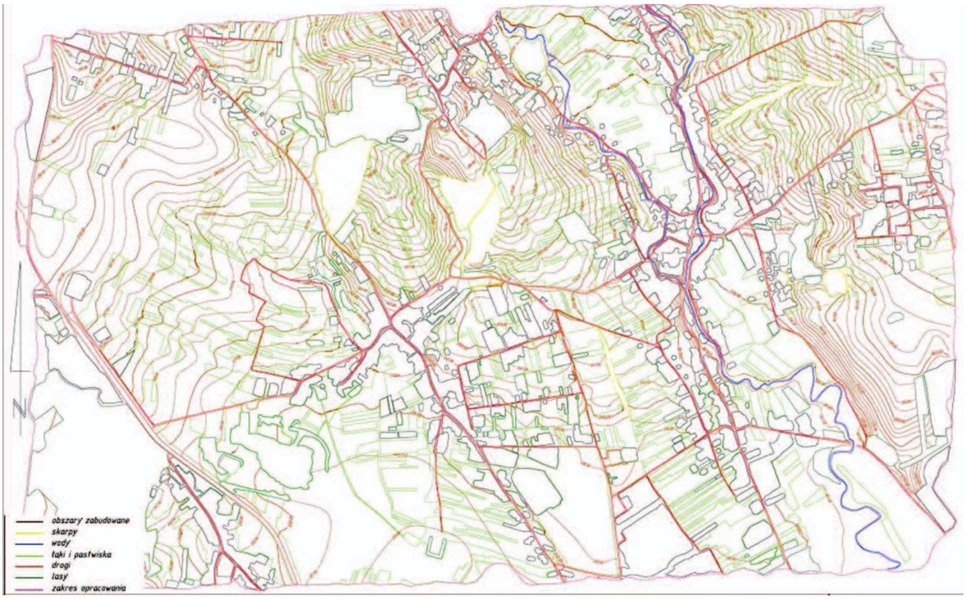
After performing properly all the orientations, stereogram is prepared for vectorisation. Stereogram vectorisation is carried out using a three-dimensional model. In the project one stereogram was created, which matches the vectorisation of an area of 1665 ha (Figure 1). Then a contour map was obtained at a scale 1 : 10 000 (Figure 2).

4. Generating a terrain spatial model and models of flood risk areas with the Surfer software

To create a visualisation of a DTM in the Surfer software one needs to choose an appropriate number and scope of points that would represent the model. In the case of this

Source: authors' study

Fig. 1. Vectorisation of a stereogram with the use of digital station "Delta"

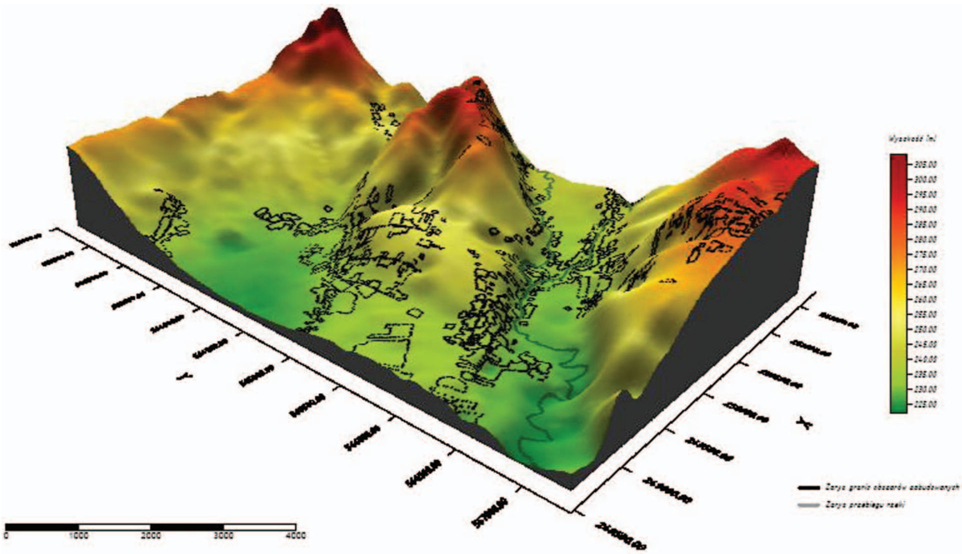


Source: authors' study

Fig. 2. Contour map at 1 : 10 000

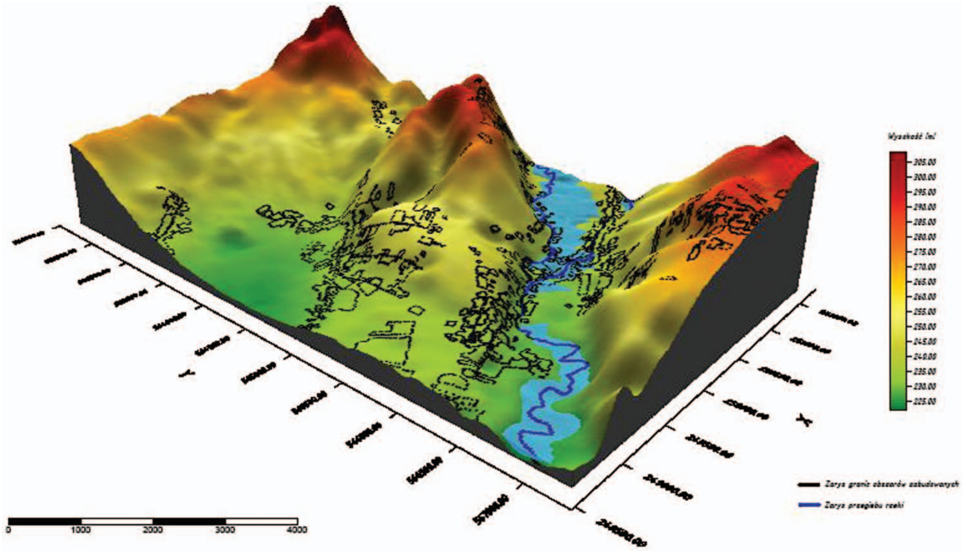
study the model consists of all the situational details, vectorised at the photogrammetric station Delta, so it includes forests, grasslands, pastures, built-up areas, waters, roads and escarpments. The digital station allows to save the project as a text file, in which vectorised objects are broken into points with appropriate geodesic coordinates. The structure of a text file generated by the Delta software requires improvement, because in each layer objects are specified, and only in them points coordinates are detailed. To proceed to creation of a model Surfer needs to constantly save files separated by spaces or tab characters. To remove the redundant lines Microsoft Excel was used. The terrain model was developed on the basis of 27 187 points. The model of a river was constructed on the points generated by means of digitalization, elevated by appropriate values of flood risk areas by 2 and 5 meters. The Surfer software automatically creates the grid on the basis of previously generated points. In the study three grid models were created: for the terrain surface, for the river with water surface level elevated by 2 m, and for the river with water surface elevated by 5 m. All grids were smoothed by Gaussian filtering.

Figures 3, 4 and 5 show Digital Terrain Models of a studied terrain, including flood risk areas.



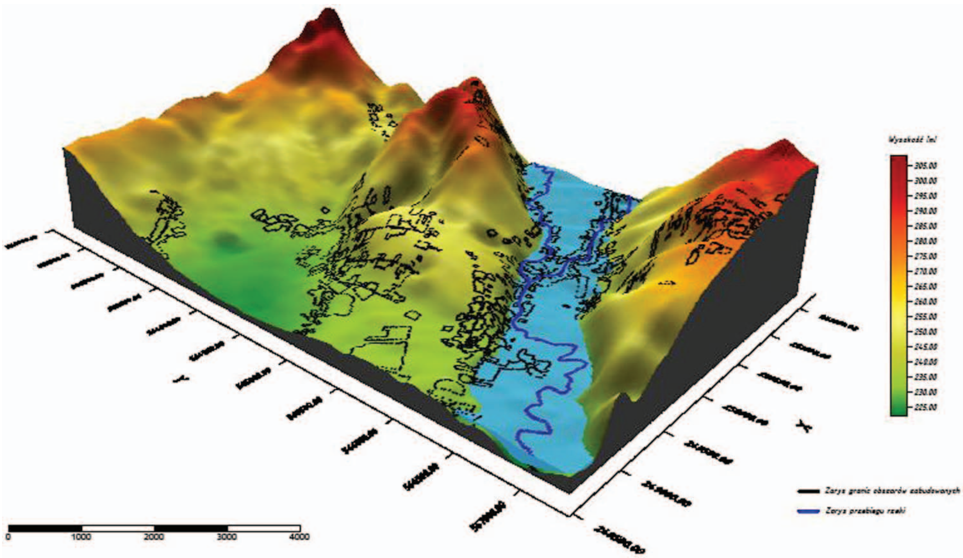
Source: authors' study

Fig. 3. The Digital Terrain Model



Source: authors' study

Fig. 4. Specifying the flood risk areas. The water surface elevated by 2 m



Source: authors' study

Fig. 5. Determining the flood risk areas. The water surface elevated by 5 m

5. Conclusions

Fast technological development leads to visualization of the surrounding world and is the source of problems related with it, and simultaneously the scientific progress in photogrammetry enables frequent use of photogrammetric materials in studies of land use and development.

The advantage of using photogrammetric methods lies in that the results of the measurements or the photogrammetric records can be worked out indoors, which means the whole process can be carried out independent of weather conditions. The photogrammetric flight, though proceeded by long preparation, is a source of rich material and its scope can encompass e.g. several communes. The accuracy of measurement in creating DTM is very high. The technological progress in measuring cameras allows for taking photogrammetric digital pictures free from errors that would have been unavoidable in the scanning of pictures. Due to the location of many built-up areas in river valleys, the specification of flood risk areas on the basis of DTM with elements of its cover, is a basis for communal and district authorities for taking preventive actions when there is a risk of floods or/and local flooding.

References

Drożdżal E. 2006. Strefy zagrożenia powodziowego. Gosp. Wod., 11, 425–427.

El-Sheimy N., Valeo C., Habib A. 2005. Digital Terrain Modeling: Acquisition, Manipulation And Applications. Artech House, Boston.

Kurczyński Z., Preuss R. 2011. Podstawy fotogrametrii. Oficyna Wyd. Politechniki Warszawskiej, Warszawa.

Litwin U., Pijanowski J.M., Szeptalin A., Zygmunt M. 2013. Application of Surfer software in densification of digital terrain model (DTM) grid with the use of scattered points. Geomat. Landmanag. Landsc. (GLL), 1, 47–57.

Rozporządzenia Ministra Rozwoju Regionalnego i Budownictwa z dn. 29 marca 2001 r. w sprawie ewidencji gruntów i budynków (Dz. U. Nr 38, poz. 454).

Prof. dr hab. Urszula Litwin
Uniwersytet Rolniczy w Krakowie
Katedra Geodezji Rolnej, Katastru i Fotogrametrii
30-198 Kraków, ul. Balicka 253a
e-mail: u.litwin@ur.krakow.pl

Dr inż. Izabela Piech
Uniwersytet Rolniczy w Krakowie
Katedra Geodezji Rolnej, Katastru i Fotogrametrii
30-198 Kraków, ul. Balicka 253a
e-mail: rmpiech@cyf-kr.edu.pl

Dawid Rakowski
Absolwent Wydziału Inżynierii Środowiska i Geodezji
Uniwersytetu Rolniczego w Krakowie