GEOMORPHOLOGIC IMPROVEMENT OF DTM-s ESPECIALLY AS DERIVED FROM LASER SCANNER DATA

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Abstract

Recent advances in laser-scanning techniques made it to a most attractive method of data acquisition for digital terrain modeling. This is due not only to the impressive level of automatization but also to the increasingly high density and precision of the points. Methods of filtering data in a preprocessing stage allow for interpolating a DTM very closely describing the terrain surface.

Further improvement of the geomorphologic quality of the surface thus interpolated can be achieved by deriving structure line information of it and introducing it as constraints into a final step of interpolation. A raster type water flow analysis is described and applied, allowing to derive the structural information needed. The impact of these constraints is then considered. Applying the method as proposed to DTMs based on data acquisition techniques other than laser scanning may also be of advantage.

A test area, a part of the Vienna Woods has been chosen. Water flow analysis is performed by SCOP.MATRIX within the frame of an alpha version of the SCOP_DTM_XX digital modeling system to come.

KEY WORDS: laser-scanner, DTM, water flow analysis

1. INTRODUCTION

Airborne laserscanning provides the means for measuring polar coordinates i.e. directions and distances between fixed-wing or rotary-wing aircraft and the reflecting objects on the earth's surface. When the outer orientation of the sensor during the scanning is known, then the measured polar co-ordinates can easily be converted into Cartesian WGS84 because of the use of GPS and INS for determining the elements of outer orientation. To transform laser points into local (national) coordinate system, the geoid undulation has to be very well known. This transformation requires data resampling which might be done either by an interpolation technique or by the nearest neighbour method.

Depending on the density of the measuring points and the width of the target grid, the resampling will cause the position and elevation errors which can only be ignored for plain and unstructured surfaces. For high quality DEMs-

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resampling errors must be minimized - which means that there should be at least two times more measurements available than needed for the target grid.

The final quality of DEM based on laserscanning is also influenced by the shadowing effect, because in built-up or forested areas a flat viewing laserbeam will reflect mostly walls or treetops and will rarely reach the ground. In the postprocessing, shadowed areas have to be recognized and measured points classified on the basis of points belonging to groundfloor, as well as those not belonging. The final quality of DEMs based on laserscanning can be improved largely through applying a qualified filtering and interpolation to laser scanner data (such a method is described in Kraus et al., 1998)

However, the contours derived from a thus filtered and interpolated laser scanner DTM will have low geomorphologic quality.

Geomorphological constraints into post-processing of laser scanner data will be included here

2. MOTIVATION

The hydrological and geomorphological tradition suggests that fluvially dominated landscapes rarely contain pits since the process of water transport and erosion precludes their development. Hydrological models that transfer water over and ultimately off a surface often fail to perform if that surface contains pits from which water may not be removed. As a consequence elevation models are often pre-processed in some way to remove such 'spurious' pits. (Wood, 1999)

3. THEORY AND ALGORITHM

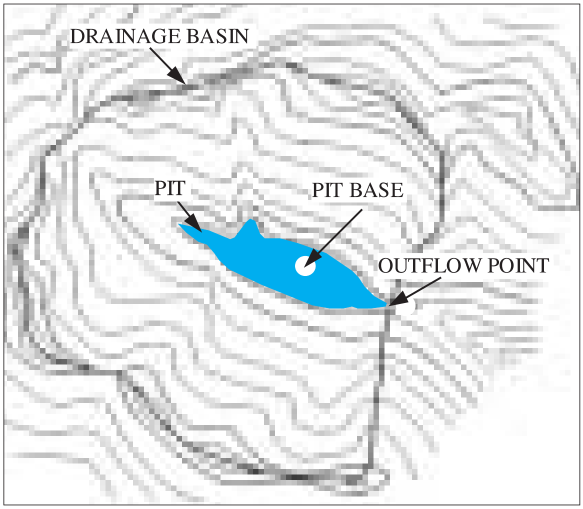
Pits are areas that lie lower as surrounded terrain surface. The lowest point of depressions is point that lies in a local concavity (all neighbours higher) and can be described by second derivatives as:

$$\frac{\partial^2 z}{\partial x^2} < 0, \quad \frac{\partial^2 z}{\partial y^2} < 0 \quad . \tag{1}$$

The standard method of identifying morphometric features is to pass a local (usually 3by3) window over the DEM and examine the relationship between a central cell and its neighbours, and on the other hand through a water flow analysis over a DEM (Rieger, 1992)

Pits identification process comes to drainage basin identification process where the lowest point of basin and outflow point are not the same. In this case the lowest point is pit base. The basin identification algorithms involve a 'basin climbing' approach where a basin outflow point is identified and the basin is recursively 'climbed' until all points flowing from the drainage divide have been covered.

Figure.1: Pit identification process



There are a number of possible solutions to remove pits from DEM. This may be achieved by either 'excavating' cells that connect the base of a pit to its adjacent downstreambasin, or by flooding pits until outflow is redirected. The first method is applied here because of several reasons:

- The results of processing are linear features (sinks) that may be well included in the interpolation as form lines.
- The impact of vegetation heights, which are not filtered out in the preprocessing stage, is greatly eliminated.

3.1 Laying the pitpath

According to the definition, pitpath is such a path that starts on a pit base, goes upwards through outflow point and flows away to its adjacent downstreambasin. It has to be set in such a way that it passes downwards by its whole length. (much more details about lying pitpath can be found in Rieger, 1992)

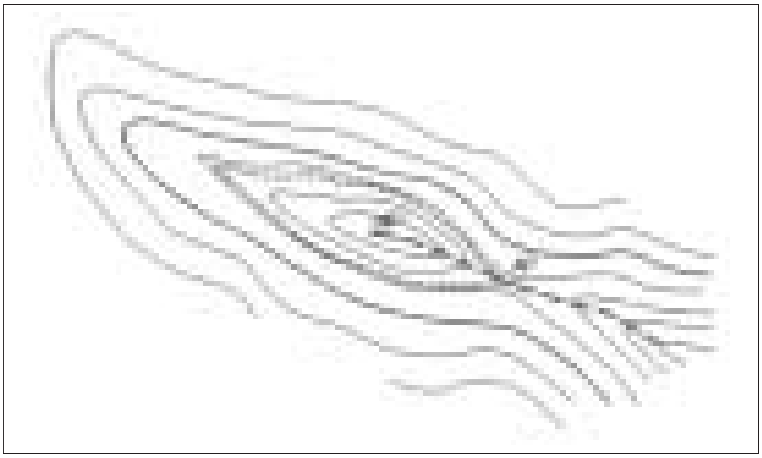


Figure 2: Pit removal process

4. THE PRACTICAL IMPLEMENTATION

The methods of geomorphological improvement of DTMs based on laser-scanner data are still under test, and here is only a pit removal introduced.

As test area an area of 91 km2 in Vienna Woods was taken. The company TopScan Germany made the data acquisition through an airborne laser scanner ALTM 1020 of Optech Inc. Canada. The whole dataset contains about 9275000 laser points. The mean distance between points was 3.1 m. The Institute for Photogrammetry and Remote Sensing produced DTMs for 360 map sheets at a scale of 1:1000. The DTM has a grid width of 3.125m resulting in 160x160 grid meshes pro one sheet. More details about this project can be found in Kraus (1997) and Kraus et al. (1997).

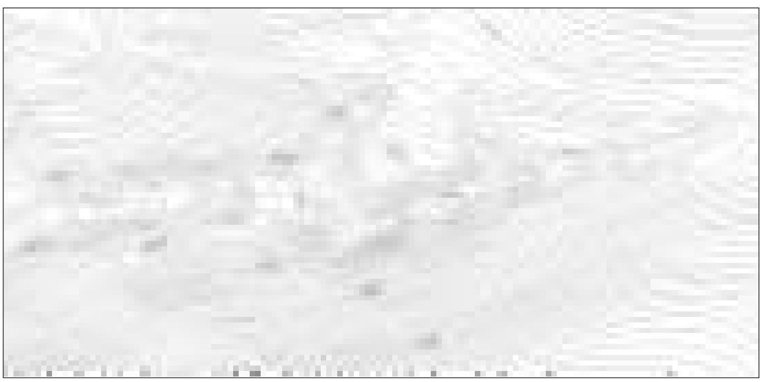
As test dataset, the final DTM was taken according to the new method of interpolation and filtering described in Kraus 1998. By means of program system MATRIX originally developed by Dr. Wolfgang Rieger, yet partly adopted for XX-framework in SCOP, the pure raster elevation model was calculated at a resolution of 1m. For visualization purposes shading and contouring are performed.

Test of a new method was done over an area where as many morphometric features as possible can be found within a small area. The Fig .3 shows such an area that comprises several catchment basins that collect water into their valleys.

Figure 3: The whole test area

Figure 4. shows the contours derived from laser scanner DTM. The artificial depressions dominate along the whole valley.

Figure 4: Contours of the test area before applying the pit removal procedure



After rasterization of DEM with resolution of 1m pro x- and y-axis, the water flow analysis was performed and pits are identified and visualized (cyan color in Fig.5.). In hydrological sense pits hold water and disable it to flow over terrain continuously. So the artificial pits have to be eliminated from DEM especially if it was interpolated for hydrological purposes, too.

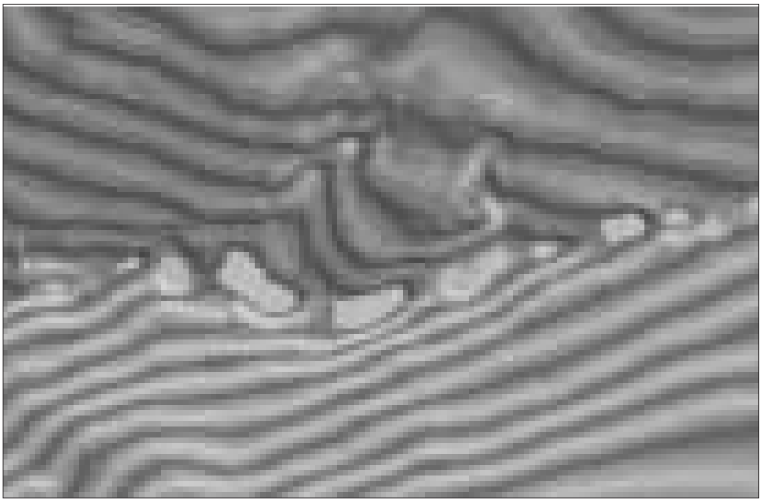


Figure 5: The visualisation of DEM with pits identified

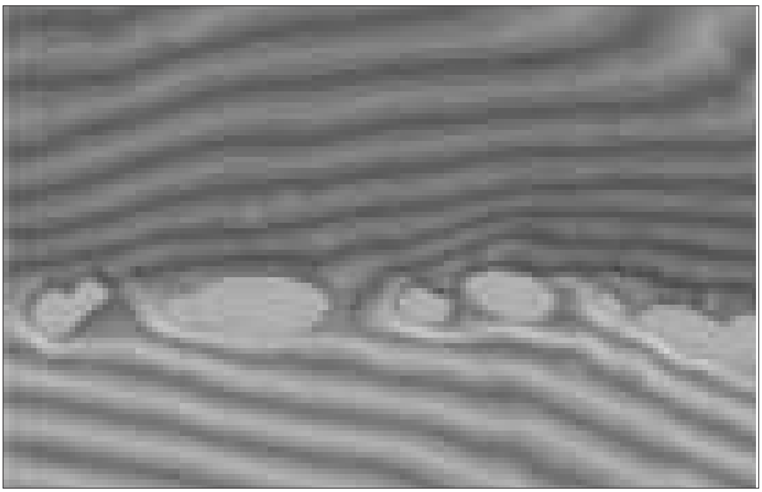


Figure 6: Pits with pitpaths

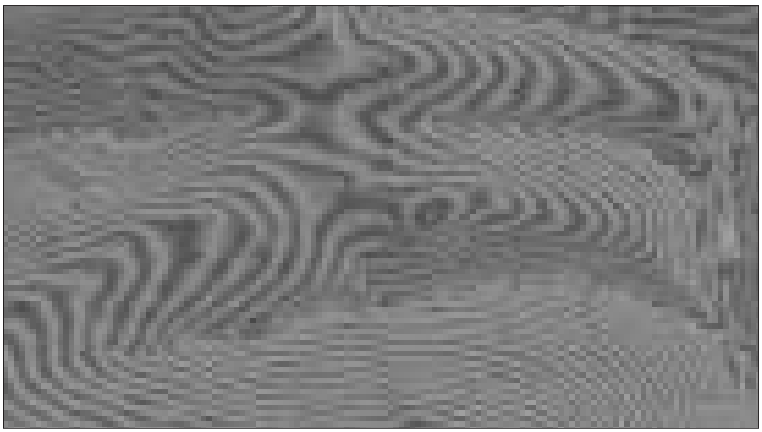
A way to let a water flow out of pit is to 'excavate' a channel from pit base to outflow point and further to its adjacent down-stream basin. These pitpaths are in raster format originally and have to be converted into vector format (WINPUT) to make a possibility to include it into the next interpolation as structure lines.

With pitpaths as formlines the next interpolation of DEM was performed. As a result, the pitsfree DEM is produced, which showing the following result after contoruing (Fig. 7.)

Figure 7: Contours of test area after pits removal process

Performing the pit identification procedure on whole dataset one more time, the procedure detects some sporadic pits, mostly without significant impact on the DEM surface. These pits are present because of interpolation and rasterization process, and mostly have no significant depth. The final result after interpolation with pitpaths included as formlines is shown in picture below.

Figure 8: The visualisation of the whole test area after pit removal process



5. CONCLUSION AND FURTHER PERSPECTIVES:

As we have seen, the water flow analysis can significantly improve the DEM in geomorphological sense.

Statistical methods of preprocessing and interpolation are well suitable to filter out the points that do not lie on the terrain and to minimize random errors. Thus interpolated surface will pass very closely to original terrain, but if we expect that interpolated surface satisfies some geomorphometric constraints, they have to be included into interpolation. Pit processing procedure, shown above, is only a simple way to include geomorphometric constraints into interpolation.

The results are promising, although the pit removal algorithm introduced here shows dificulties in areas where pits really exist and should remain included in DEM, too. This problem leads to be solved at the preprocessing phase where the clasification of pits should be done. This clasification should be performed according to the size of a pit and to average penetrating rate of laser beam. After clasification, the big pits should be masked out for further processing.

Further, the drainage lines (rivers) detection, and including it into interpolation could significantly improve geomorphological consistency of DEM. How derived rivers can impact interpolation of DEM will be investigated.

The pits identification and processing algorithms are realised by means of softvare MATRIX (developed by Dr. Wolfgang Rieger), and will be included into SCOP-XX framework as a module named HYDRO. At this stage this module does some more analysis about water summation, rivers and catchbasins identification, but is still being developed.

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REFERENCES

Kraus, K., Pfeifer, N., *1998. Determination of terrain models in wooded areas with airborne laser scanner data, ISPRS Journal of Photogrammetry & Remote Sensing 53, p.p. 193-203*
Rieger, W., *1992. Hydrologische Anwendungen des digitalen Gelandemodelles, Disertation, Geowissenschaftliche Mitteilungen, Heft 39, IPF TU Wien.*
Rieger, W., *1992. Das Programm MATRIX - User's Manual*
Wood, J., *1996. The geomorphological characterisation of Digital Elevation Models, PhD Thesis, University of Leicester, UK.*
Wood, J., *1999. Visualising the structure and scale dependency of landscapes, Presented paper at Annual Conference of the Royal Geographic Society, Leicester University, January 5th-8th, 1999.*

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