A GRID-BASED EDGE MODEL FOR THE WAVELET TRANSFORMATION OF HYBRID DTM

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KEY WORDS: Wavelet Transformation, DTM, Hybrid Models, Multi Level Model

ABSTRACT

The wavelet transformation of hybrid terrain models is gaining more and more significance. The complex geo-information can nowadays only be effectively managed in hybrid terrain models. Essential additional information for the pure height model are space curves in the form of relief-related curves. The 2D wavelet transformation of height values on a regular grid is possible without any problems. New problems are produced in hybrid models. In this paper to be prepared a method is introduced how the edge information can be represented on the grid of the height model. With this grid-based representation of the edges, the wavelet transformation with consistent data sets in the wavelet domain is possible without any problems.

1 INTRODUCTION

The digital terrain model has become a central storage carrier for height information. The wavelet transformation is being used more and more to analyze the relief structure on the one hand, on the other hand, to noticably reduce the data size through compression. The 2D wavelet transformation of heights on a regular grid (Fig. 1) is possible without any problems (e.g. Wickerhauser 1994). The 2D wavelet transformation of space curves is possible, too (Beyer 1999). New problems are produced in hybrid models (grid-based data with added information, particulary terrain edges, see Fig. 2). As data structure for the height model a height matrix with the height values of grid points and for the edges mostly traverses as sequences of x,y,z-coordinates are used (e.g. IPF 1991). Hereby, the discrete points are generally not on the grid points of the height model. In the wavelet transformation of this differently structured information (signals) the spatial relation in the wavelet domain is lost.

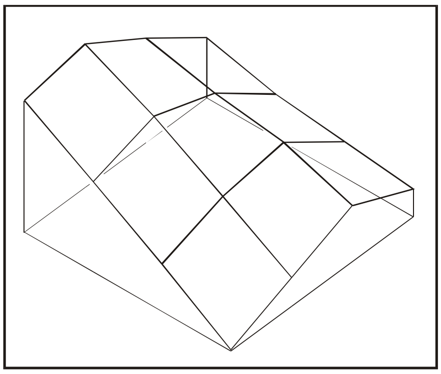

Figure 1. Regular DTM

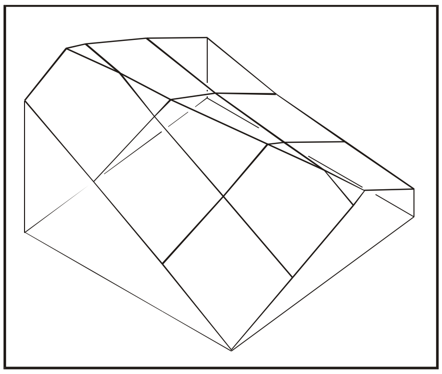

Figure 2. Hybrid DTM

It is researched wether and how the terrain edges with the same kind of wavelet transformation can be submitted in order to receive a uniform data structure as well as a spatial relation between the height model end the edge model in the wavelet domain. In this paper a method is introduced how the edge information can be represented on the grid of the height model. With this grid-based repressentation of the edges, the wavelet transformation with consistent dataa sets in the wavelet domain is possible without any problems.

2 THE ONE DIMENSIONAL CASE

If the problem is first viewed in the one-dimensional case, there is a wavelet transformation of a non-smooth function, meaning a curve with breaks. The function is to be given discretly onto an equidistant grid. Additionally, the x,y-coordinates of the break points, whose x-coordinaates generally do not lie on the grid, are to be known.

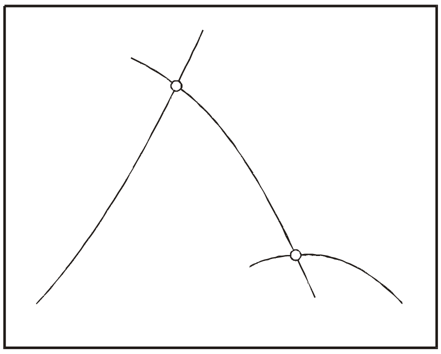

Figure 3. Crossing of two smooth curves

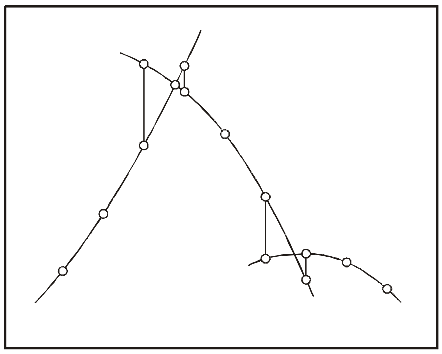

Figure 4. Differences between the height values of the continued curve

A break in a profile can be seen as a crossing of two smooth curve pieces (Fig. 3). If each of the two curve pieces is continued past the break point Q_k , there will be differences $\tilde{y}_i, \tilde{y}_{i+1}$ between the height values of the continued curve $\hat{P}_i, \hat{P}_{i+1}$ and the height values of the original profile P_i, P_{i+1} in the respective grid point following (Fig. 4). These can be found through linear extrapolation (Fig. 5) and to be stored as grid values (edge signal) of a second grid model (secondary compesation model, see Fig. 6). From this, together with the height values of the original profile (profile signal), the coordinates of the break point can be reconstructed as crossing of two curves (Fig. 7).

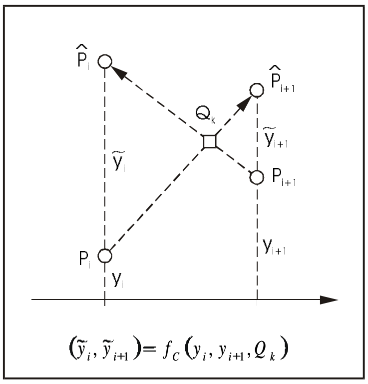

Figure 5. Extrapolation

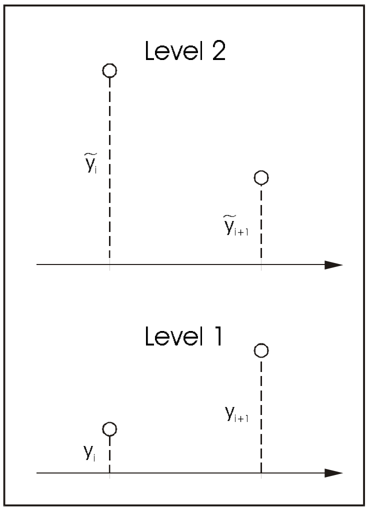

Figure 6. Storage in two levels

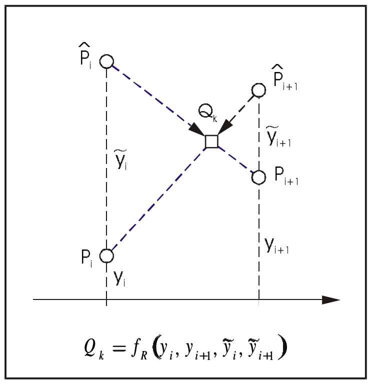

Figure 7. Reconstruction

In the compensation model the break is localized by its position in the matrix, and thus a spatial relation to the profile signal is possible in the wavelet domain. In the transformation of the two signals (profile signal and edge signal) in the wavelet domain the different properties of the two signals (natural terrain profile or rather local "rectangular" signal) can be taken into consideration. This means on the one hand the choice of the wavelet and on the other hand the stating of the compression rate for the data compression following. In the profile signal by means of the wavelet transformation mostly a goal-oriented filtering is intended while in the edge signal the significant edge information is to be kept intact. In the backward transformation from the wavelet domain the edge signal with its "rectangular" pulses remains intact if the choice of the wavelet, even in a relatively high compression rate. In the reconstruction of the profile the break is placed onto the smoothed profile signal like a hat.

All in all, a generalization of the relief in the wavelet domain, keeping intact the edge information, is possible. Especially the spatial relation in the plane (by using an equal grid) as well as in the height (using principle of superposition) is kept intact in the wavelet transformation between the profile and the break.

3 TWO DIMENSIONAL DTM

In the two-dimensional case (Fig. 8) this principle leads to the extrapolation of surfaces which, however, can be traced back to the one-dimensional case, whereby the grid planes (the vertical surfaces above the grid lines) are viewed. The extrapolation of the surface is approximated by the extrapolation of the boundary grid lines of the surface. The intersections of grid lines are used as points of the edges. These are the intersections of the edge polygon with the grid planes (Fig. 9).

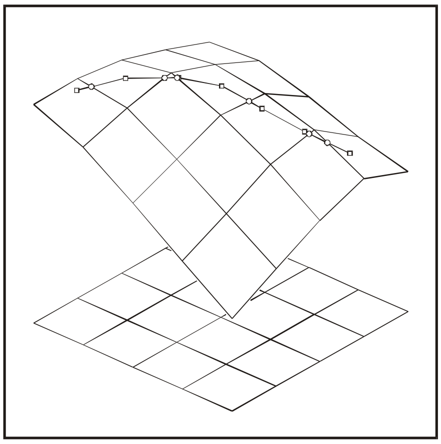

Figure 8. The given hybrid data

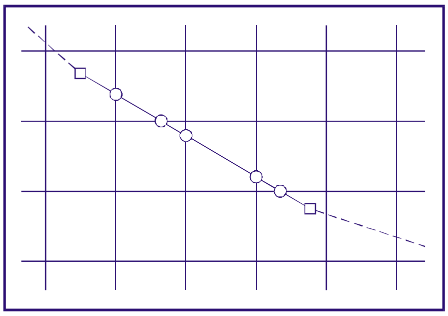

Figure 9. Computing of grid intersections (○) by the given break line points (□)

Hereby, two topologically different cases can take place which influence the categorization of the extrapolated values to the matrix elements of the compensation model. In the first case (Fig. 10) the intersections of the grid lines lie on opposite grid lines. The extrapolation on these two grid lines causes four differences, which can definitely be appointed to the four grid points.

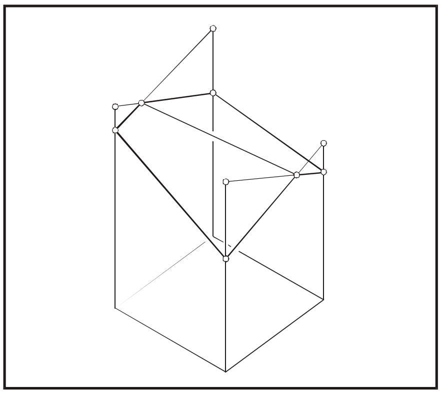

Figure 10. The intersections of the grid lines lie at the opposite grid lines

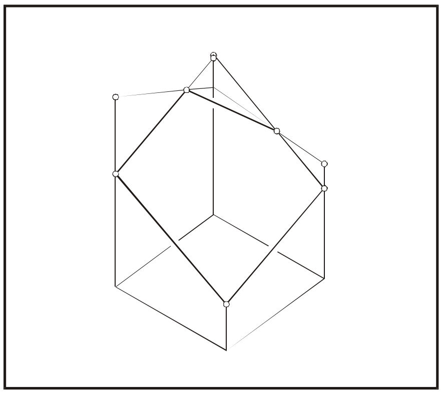

Figure 11. The intersections of the grid lines lie on neighboring grid points

In the second case (Fig. 11) the intersections of the grid lines lie on neighboring grid lines. The extrapolation on these two grid points causes four differences, two of which must be appointed to the same grid point. As this deals simply with approximations of one and the same differences of the to be extrapolated surface, a suitable weighted mean can be stored in the grid model of the differences.

The method was successfully tested on real DTM-data. An example you can see in Fig. 12.

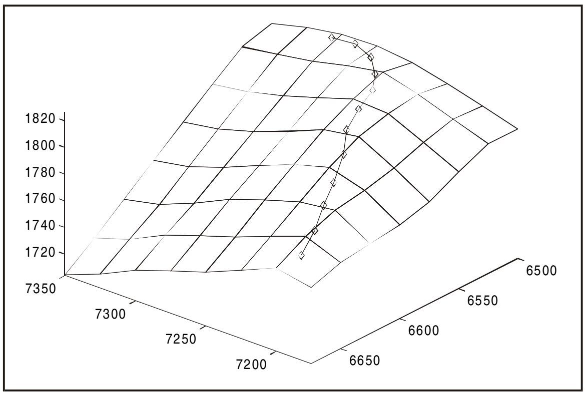

Figure 12. Real DTM with a break line

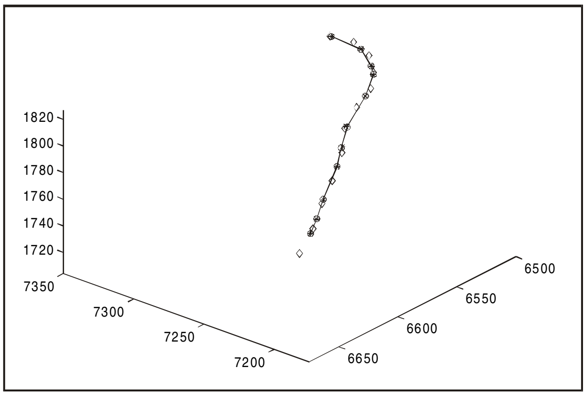

Figure 13. The given break line points (◇), the grid intersections (✳) and the reconstructed grid intersections (O)

4 CONCLUSIONS

In the DTM the heights of the terrain over a regular grid are usually saved in a matrix (level 1). For the wavelet transformation, the matrix-saving is advantageous. The usually irregular lying break lines in a hybrid DTM can be described by their grid intersections. By the extrapolation of the boundary grid lines of the surface on the grid points it is possible to save the edge information in a grid matrix, too (level 2). Problems develop only when the edge are (positioned) too dense. Possibilities to solve them result from the extension of the two-level-model to a multi-level-model, which is additional able to take/admit more space-related geo data.

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