Digital terrain model quality assessment: insights on how to minimise and handle common artefacts

Olivier Bonin, Frédéric Rousseaux

Institut Géographique National, COGIT Laboratory,
2-4 avenue Pasteur, F-94165 Saint-Mandé CEDEX
phone: +33.1.43.98.84.09
fax: +33.1.43.98.81.71
{olivier.bonin, frederic.rousseaux}@ign.fr

Digital Terrain Models – DTMs (resp. Digital Elevation Models – DEMs) are numerical models for the ground (resp. an envelope of the ground and objects on the ground) (4). As numerical models, they are computed from a set of height measurements generally irregularly scattered over the ground.

The spatial distribution of these measurements, and the method used to estimate the model (tesselation in case of polygonal irregular networks, interpolation in case of lattices) cause well-known artefacts (5), and have a great impact on the shape of the resulting relief (1; 2; 3; 9). These artefacts have generally a greater impact on DTM quality than noise and imprecision in the measurement process. We study here the nature of these artefacts and their typical location, to highlight their effect on geographical applications. We present algorithms to correct them as much as possible, and provide a methodology to predict the location of possible errors.

We provide numerical illustrations of these artefacts in case of high resolution DTMs created from contour lines, by comparison with an extremely high resolution DTM obtained by LIDAR. We construct DTM with several classical algorithms. We consider three interpolation methods: Inverse Distance Weighted (GRASS 5), Regularised Spline with Tension (6), and kriging. We also evaluate tesselation methods: standard Delaunay triangulation, and enhanced Delaunay triangulation, i.e. Delaunay triangulation corrected as much as possible from artefacts and enhanced by exogeneous vector data. Figure 1 illustrates summit correction.

We focus on the impact of these artefacts on the elevation, slope and aspect values computed from the DTM, as these terrain parameters are useful for many geographical applications. Figure 2 shows kernel density estimation of elevation errors for three of the five DTMs.

We illustrate the gain of precision obtained by the use of artefact correction algorithms such as (8), and by coherent integration of exogeneous vector linear data (7) which leads to the enhanced Delaunay triangulation. Note that even for the best DTM, that is to say the enhanced Delaunay triangulation, elevation error distribution is not Gaussian (cf. quantile-quantile plot from Figure 3), suggesting that not all errors are measurement errors.

However, the fact that not all artefacts can be corrected suggests that the artefacts come from interpolation or triangulation, but also from the very nature of terrain and from its shape. The investigation of the origin of artefacts, and the study of their localisation leads us to propose an *a priori* characterisation of DTM quality through potential error maps. The computation of potential error maps relies on morphometric parameters (10), which raises the need for efficient and robust morphometric parameter computation algorithms. This approach enables local quality prediction without the help of reference elevation sources.

Bibliography

[1] Carter, J. R. (1992). The effect of data precision on the calculation of slope and aspect using gridded dems. *Cartographica*, 29:1, 22–34.

[2] Eklundh, L. and Martensson, U. (1995). Rapid generation of digital elevation models from topographic maps. *International Journal of Geographic Information Science*, **9**, 329–340.

[3] Florinsky, I. (1998). Accuracy of local topographic variables derived from digital elevation models. *International Journal of Geographic Information Science*, **12**, 47–61.

[GRASS 5] GRASS 5. `http://www.geog.uni-hannover.de/grass/`.

[4] Hutchinson, M. F. and Gallant, J. C. (1999). *Geographical information systems (second edition), Volume 1, Chapter 9: Representation of terrain*. Wiley, edited by Longley, Goodchild, Maguire and Rhind.

[5] Jaakkola, O. and Oksanen, J. (2000). Creating dems from contour lines: interpolation techniques which save terrain morphology. *GIM International*, **14**, 9, 46–49.

[6] Mitasova, H. and Mitas, L. (1993). Interpolation by regularized spline with tension: I. theory and implementation. *Mathematical Geology*, 25, 641–655.

[7] Rousseaux, F. (2004). Etude de l'impact de la représentation du relief sur les applications. *Revue Internationale de Géomatique*, to appear.

[8] Rousseaux, F. and Bonin, O. (2003). Towards a coherent integration of 2d vector linear data into a dtm. *in proceedings of the 21st ICC*.

[9] Wechsler, S. (2000). *Effect of DEM uncertainty on topographic parameters, DEM scale and terrain evaluation*. Ph.D. Dissertation, University of New York, College of Environmental Science and Forestry.

[10] Wood, J. (1996). *The geomorphological characterisation of digital elevation models*. phD Thesis, Department of Geography, University of Leicester, U.K.

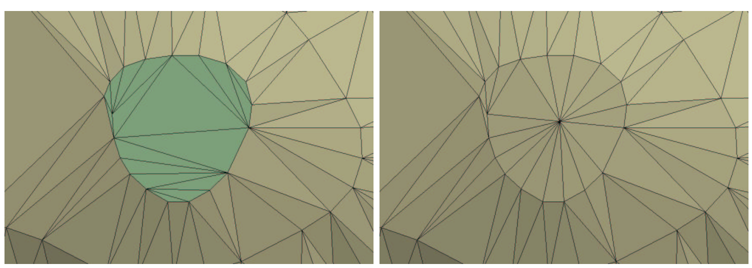

Fig. 1. Example of summit correction

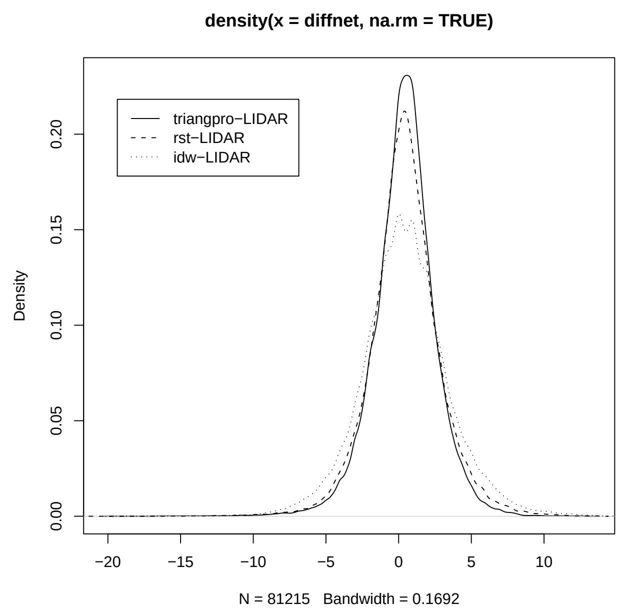

Fig. 2. Kernel density estimation of elevation differences for three DTMs

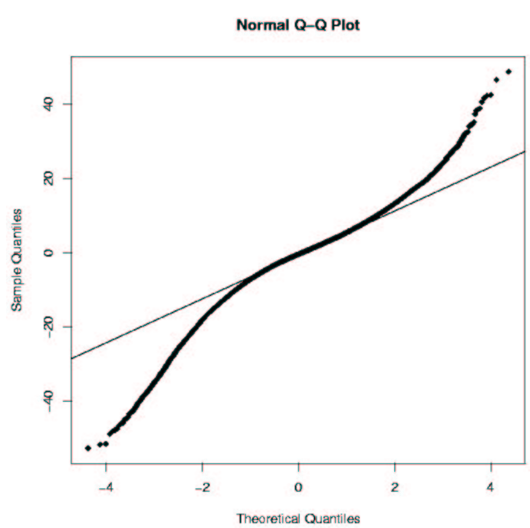

Fig. 3. Quantile-quantile plot of elevation difference distribution against normal distribution