STRUCTURAL PARAMETERS FOR HYBRID DTM GENERALIZATION

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Abstract

Digital Terrain Models (DTM) generalization results of great potential for cartographic and photogrammetric aplications, as well as for analysis processes in Geographic Information Systems (GIS) where the spread of DTM acquires greatest significance, due to the variation of scale when viewing, changes of resolution as well as the use of different cartographic databases, multimedia cartography, cartography on demand etc; for both consulting analysis as well as showing results.

This study consists on two main objectives: the first one consists on determine optimal parameters of witch depends a hybrid DTM generalization on. And the second one consists on stablishing optimal analysis processes to evaluate the effects caused by the defined parameters on the DTM. Once these objectives have been solved DTM generalization could be automated with a high degree of accurate quantifying application ranges for each defined parameter in terms of the relief.

The area selected for study is a very flat area with a mountain of highly pronounced relief, so the study of the behaviour of the generalization in widely differing gradient ranges is possible. The points cloud for generating the DTMs at two different scales has been obtained by automatic correlation processes. Generation of the DTMs at each scale will be via a regular grid (RR) structure.The break lines as well as the singular points have been captured using conventional restitution processes for each scale independently. The resultant DTMs are Hybrid DTMs, generated by a regular matrix of different sizes for each scale witch cells are adjusted by hyperbolic paraboloids, and with their corresponding break lines and singular points.

The behaviour of the break lines and singular points regarding the generalized grid must be studied. Firstly, by isolating these components into their basic units, in order to obtain chained, but independent, break segments for study (with different lengths, directions and gradient). Within a cell *i* belonging to the generalized grid, break segments will coexist with singular points from the capture process as well as the vertices defining the original grid. Depending on the response to the process of generalization, these items will be classified as significant or insignificant segments and significant or insignificant points.

To do so different levels of generalization over 9 fundamental parameters will be defined by 12 semi-automatic processes. Defined parameters are: grid size, segment length, average angle of segments respect generalized grid, zenithal distances from the ends of the break segment to the cell in the original and generalized grids and zenithal distances from a singular point to the cell in the original and generalized grids. Implemented processes are the nine processes that correspond with the calculation of each of the nine parameters defined appliying variations at predefined intervals of tolerance, 2 analysis processes that evaluate calculated distances of points and segments respect fixed tolerances and finally, once elements have been correspondingly filtered on the basis of the previous parameters, the joint evaluation of all elements not yet classified will be evaluated on the basis of their status in relation to the rest of the elements.

The results obtained show that implemented processes work perfectly for evaluating the elements without loss of information, which means that 100% of the elements are evaluated by the algorithm and consecuently classified. The comparison of the generalized DTM with respect to the original one has shown a high degree of agreement that in areas of gentle relief results of 97.7% (95.6% in the worst case studied), 88.9% in areas of average relief (84.3% in the worst case studied) and 82.6% in steep relief (worst results obtained below 75% in cases of extreme relief). These results supose that the generalization of large scale Hybrid DTMs, when the only variable considered is the level, has a high degree of agreement with a DTM obtained directly on lesser scales, for the processes implemented according to the parameters described.

After all we can conclude that the automation of the process shows its direct application in mass-produced GIS applications or cartographic processes, which results in high performance and considerable cost reduction. The grid of the generalized Hybrid DTM proves to be very accurate because of the use of original data from a larger scale and therefore the metrical accuracy is maintained. Besides, the generalization represents considerable economic savings versus a new data collection and processing.

The research results are very satisfactory, despite having established specific application ranges to apply in other areas, it is a long process susceptible of greater automation; and even more so if research continues down this line with the aim of including planimetric elements together with altimetry. In this sense, the sequence of analysis and the dependence of the filtering in the indicated order is decisive to obtain a correct evaluation of the elements and should be particularly considered when including new parameters.

Keywords: DTM; Generalization; GIS; Cartography; Photogrammetry

1. Introduction

DTMs emerged with the development of digital maps and have their origin in the Photogrammetry Laboratory of the Massachusetts Institute of Technology (Miller and Laflamme, 1958). They were constructed by establishing a correspondence relationship with reality whose variants can produce models of different characteristics through a set of numerical data (Berry, 1987). DTMs are digital elements encoded and structured in such a way that they express functional and topological relationships, and therefore they must have internal structure and the variable they represent must be quantitative and continuous.

For generating DTMs indirect methods have revealed the most suitable for mass data acquisition over large tracts of land. The most common are those based on entities defined by coordinates forming irregular triangular network (TIN) structures and those based on the average values of the elementary surface units covering the terrain via a distribution in the form of a regular matrix (RR), using a constant amount of information per unit area, or irregular matrices based on the hierarchical grouping of elementary units of variable resolution (Quadtree). Although TIN structures have traditionally been more accepted by numerous researchers who generate DTM using Voronoi Diagrams (Okabe et al., 1992), there have been many authors who have also defended the RRs for being more open to analysis, due to its more homogeneous adaptability in all types of relief (Carter, 1988). But in both cases there an obvious need for the use of break lines to achieve a greater degree of adaptation to reality, so both TIN and RR are shown to be insufficient by themselves. In response to this need, DTMs based on RR were shown with increasing clarity to be optimal [Ackerman and Krauss, 2004) compared with the traditional methods supported by TIN which, nevertheless, some authors continue to defend (Thurston, 2003).

Studies about generalization over DTMs based on contours derived from cartographic field can be found (Brassel and Weibel, 1988) but not on TIN or RR structures. Derived from these, research has emerged whose results of independence, locality and globality are extrapolable to the case of DTM via classifications of elements in groups according to the geometric nature of the calculations (Moore et al.1988), structural generalization studies, numerical, numerical categorisation and categorical generalization applicable to matrix DTM (McMaster and Shea, 1988), global filtering methods, selective filtering and heuristic generalization for flexibility and adaptability to the variations and types of terrain (Weibel, 1995), generalization studies oriented to the realistic simulation of terrain data for viewing (Garland and Heckbert, 1997), analysis of the understanding of the process in itself using statistical, morphological and resampling generalization methodology (Gesch, 1998) or generalization techniques for models of particular structures based on contour maps (Li and Sui, (2000).

In this study, an analysis of the behaviour of the DTM will be carried out, when compared with a process of specific generalization for Hybrid DTMs based on the definition of some parameters that affect it.

2. Structural parameters definition

The points cloud for generating the DTMs have been obtained by automatic correlation processes at a scale of 1/5000 and 1/25000. The break lines as well as the singular points have been captured using conventional restitution processes for each scale independently. Generation of the DTMs at a scale of 1/5000 and 1/25000 will be via a regular grid (RR) structure. Within each cell i belonging to the generalized grid, break segments will coexist, obtained by the intersection of break lines with the original grid and/or with other break lines, and singular points. Depending on the response to the process of generalization, these items will be classified as Significant Segments, Insignificant Segments, Significant Points and Insignificant Ponts.

The different levels of generalization will be defined by a semi-automatic process, conditioned by the following parameters (Figure 1):

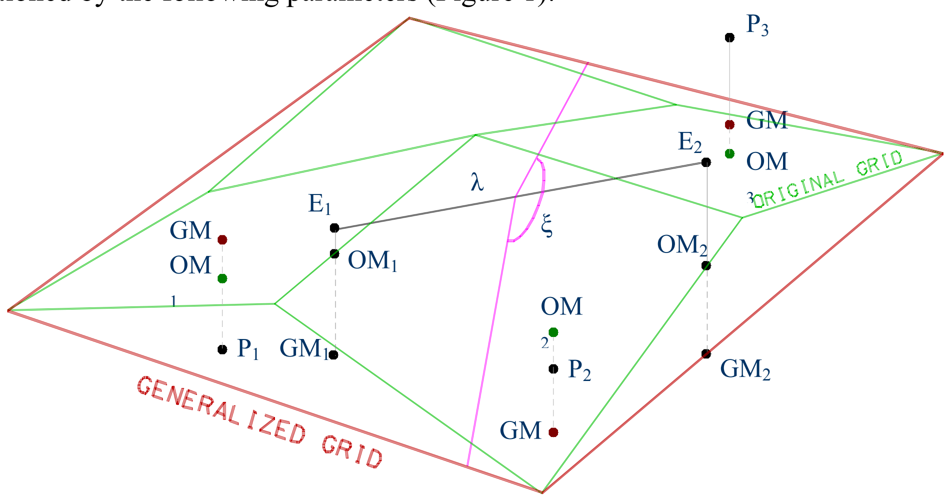

Figure 1. structural parameters defined in each cell of the grid

- Grid size (μ): number of cells (rows and columns) of the original grid used for the generation of each generalized grid cell.
- Segment Length (λ): geometric length of the break line segment intersecting with the original grid or another break line in the same cell.
- Average angle (ξ): angle of intersection of a perpendicular plane, to the break

line contained in each cell at its midpoint, with the edges of that cell.

- Zenithal distance 1 and 2 (Δ_1 and Δ_2): vertical distances from the ends of the break segment E_1 to the cell in the original grid (MO_1).
- Zenithal distance 3 and 4 (Δ_3 and Δ_4): vertical distances from the ends of the break segment E_1 to the cell in the generalized grid (MG_1).
- Zenithal distance 5 and 6 (δ1 and δ2): vertical distance from point P to the cell of the original mesh (OM) and the generalizated mesh (GM).

Once the parameters have been defined semi-automatic procceses will be applied to generalize the DTM. There are 3 blocks of processes:

- DTM Generation processes: where a regular grid is generated through the original mesh of points and the break lines captured.
- Structural parameters calculation processes: where the value of the 9 defined parameters is calculated.
- DTM generalization processes: where variations of ξ and λ at pre-determined intervals will be applied to the previous results in order to analyse their impact on the generalized DTM.

3. Results

The results obtained show that implemented processes work perfectly for evaluating the elements without loss of information, which means that 100% of the elements are evaluated by the algorithm and consecuently classified (Table 1).

	Original elements			**Generalizated elements**					
Block	Singular Points	Break Segements	Σ	Significant Segments	Insignificant Segments	Deleted Segments	Significant Points	Deleted Points	Σ
Gentle relief	6	48	54	8	5	31	8	2	54
Average relief	24	416	440	221	64	120	17	18	440
Steep relief	12	1939	1951	1314	411	194	19	13	1951

Table 1. Generalization process applied in 3 different reliefs from 1/5000 to 1/25000

The comparison of the generalized DTM with respect to the original one has shown a high degree of agreement that in areas of gentle relief results of 97.7% (95.6% in the worst case studied), 88.9% in areas of average relief (84.3% in the worst case studied) and 82.6% in steep relief (worst results obtained below 75% in cases of extreme relief). These results supose that the generalization of large scale Hybrid DTMs, when the only variable considered is the level, has a high degree of agreement with a DTM obtained directly on lesser scales, for the processes implemented according to the parameters described.

4. Conclusions

The generalization of Hybrid DTMs, when the only variable considered is the level, has shown a high degree of dependence with the structural elements defined. The applied processes of generalization works perfectly from the point of view of the results obtained about significant and insignificant elements according to the 3 types of relief selected. The research results are very satisfactory, and work is continuing in this direction with the evaluation of new parameters which will allow the inclusion of planimetric elements permitting the application of the algorithms developed in areas with buildings.

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