Chapter XLIII
Geometric Quality in Geographic Information

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INTRODUCTION

Both this article, referred to as Article I, and another one, Article II, entitled "**Geometric Quality in Geographic Information IFSAR DEM Control**", published in this encyclopedia propose a method to evaluate the geometric integrity of Digital Elevation Models obtained by different techniques. Therefore, the theoretical aspect of the method to evaluate the geometric integrity and different stochastic hypotheses will be presented in both of them. Herein, we consider the classical topographic or aerial photogrammetry stereo images method (included ASTER or SPOT images) and we assume consistent stochastic hypotheses. In the Article II we consider Interferometry SAR (IFSAR) techniques and the stochastic hypotheses are specific according to the particular geometry involved in this technique.

A typical way to build surface numerical models or Digital Elevation Models (DEM) for Geographical Information Systems (GIS) is by processing the stereo images obtained from, for example, aerial photography or SPOT satellite data. These GIS can perform many computations involving their geographic databases. The quality control of a geographic database and in particular the topological and geometric integrity are, therefore, important topics (Guptill & Morrison, 1995; Harvey, 1997; Ubeda & Servigne, 1996; Laurini & Milleret-Raffort, 1993). The geometric quality control of the stored DEM is what we are concerned with here. «Quality» means the geometric accuracy measured in terms of the difference between a DEM and a reference DEM (R-DEM). We assume the R-DEM is a faithful model of the actual surface. Its point density may be greater than the DEM point density.

BACKGROUND

In the literature, several unsatisfactory solutions were proposed for the DEM control with respect to a reference. A critical problem in the error estimation (evaluated using the difference referred to in the previous paragraph) is to establish for each selected point of the DEM the corresponding homologous point in the R-DEM. Other kinds of problems and errors are related to the existence of aberrant points, systematization, etc. These problems were studied for horizontal errors in maps in (Abbas, 1994; Grussenmeyer, 1994; Hottier, 1996a). These authors found that the dissymmetry model-reference was the most important factor to determine homologous pairs.

Several solutions have been proposed for the 'punctual control method' (recognition algorithms, filtering methods, adjustment of histograms to theoretical laws) without obtaining completely satisfactory results (Dunn et al, 1990; Lester & Chrisman, 1991). Later, (Abbas, 1994; Grussenmeyer, 1994; Hottier, 1996a) present an alternative to the punctual control method: the 'linear control method' based on the dissymmetry of the Hausdorff distance.

Habib (1997) analyzes precision and accuracy in altimetry and mentions some of the proposals of the last decade for the elevation control of quality.

In the case of the DEM's, to assess the difference that gives rise to the error we wish to compute, we need to identify without ambiguity each point M in the DEM with its homologous point P in the R-DEM.

Two reasons make this task difficult:

1. Many points M are not identifiable, those situated on regular sides, which are indistinguishable from their neighbors. Potentially identifiable points are those located on sharp slope variations, and possibly those with zero slope (tops, bottoms and passes).
2. A point identifiable on the DEM is not necessarily identifiable in the R-DEM, because of a difference in scale ("generalization") or aberrant errors.

To find identifiable homologous pairs of points is difficult for an operator. Automating this is a very delicate process.

In the case of the geometric assessment of a DEM from an ASTER (Advanced Spaceborned Thermal Emission and Reflection Radiometer) (Hirano et al., 2002) profiles or benchmarks (particular points) are used for the elevation accuracy assessment. This elevation accuracy assessment refers to the vertical error of the DEM. However, using profiles the horizontal error is not taken into account and also there is a model-reference discrepancy. Moreover, the choice and number of the benchmarks might not be a good stochastic sample of points. On the other hand to estimate the elevation error (σ_z), by means of the commonly used (vertical distance) estimator, gives poor results with an irregular surface because it introduces a systematic error (Zelasco, 2002).

In light of the above difficulties, in (Zelasco & Ennis, 2000) an estimator for the variances of the vertical and horizontal errors were proposed. The values obtained for the estimator, according to the type of terrain, its unevenness, and the number of sample points in the DEM, were studied using simulations in (Zelasco et al., 2001; Zelasco, 2002). Throughout these studies, it is assumed that the errors in elevation and in the horizontal plane are independent Normal random variables - in agreement with Liapounov's theory (Hottier, 1996b). This proposed method is called the Perpendicular Distance Estimation Method (PDEM).

Let $e(M_k)=M_k$ - P_k where M_k, P_k are the k selected homologous pairs of points in the DEM and R-DEM respectively. Estimating $\sigma^2(e)$ (variance of the error as distance between M and P) without measuring each vector $e(M_k)$ completely, is the key advantage of the proposed PDEM. Only the projection of each $e(M_k)$ in particular directions