Calibration of interferometric synthetic aperture radar digital elevation models (DEM) using error surface interpolation methods.

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Digital elevation models (DEM) are numerical representation of terrain elevation data that has been used in a wide range of spatial analysis applications. The principles for acquisition, storage, management, update, spatial analysis, visualization as well as integration with other systems are reasonably well known. However, as DEM applications are becoming increasingly more widespread, so does concern about the quality of the available elevation data and the propagation of DEM errors through the analysis. It is now well known by analysts and researchers that the results of many DEM-based quantitative operations are significantly affected by the magnitude and also by the spatial distribution of elevation errors in DEM. However, currently available DEM's frequently report only the average magnitude of errors as the root mean square error (RMSE), which does not provide information on systematic bias nor on the spatial patterns of the DEM errors (Heuvelink, 1998). A very important critical point to consider when remote sensing techniques are used for mapping earth resources is the geometric quality and error assessment of data and information products involved throughout the entire process. In the case of 3D data for DEM applications the most suitable and general form to evaluate errors and provide corrections refinement is based in the establishment of a set of mapping functions between feature's positions present in DEM and its corresponding in a cartographic reference frame. So far, many efforts have been made to solve registration and geometric correction problems based in this kind of approach (Audette et al, 2000; Gruen & Akca, 2005). However, relevant research contributions are still required in this field, mainly for development of non-rigid and some degree elastic correction and registration methods, as well as to provide control and certify DEM internal quality (Pottmann et al, 2004). It is an essential issue for topographic mapping applications. The present work deals with DEM generated by synthetic aperture radar (SAR) interferometry. The main objective is developing a method for DEM correction providing statistical estimation of the method's efficiency. The DEM's presently used was generated by SAR P band fully polarimetric system and HH polarization in X band. Data was collected in two-pass mode for P band interferometry and single-pass mode for X band interferometry. SAR radiation in X band do not penetrates into forest so resulting DEM is related to top forest cover, while SAR radiation P band penetrates into forest canopy up to reach ground level, so producing a DEM related to forest floor. If both models from X and P band are submitted to adequate geometric correction and effectively calibrated the resulting difference between them will produce a forest digital height model. This product is an important request for many current applications. The methodology used in this work mainly consists in the following topics: SAR data acquisition; field topographic control structure determination; geometric quality evaluation of original DEM models; development of strategies and algorithms for DEM error correction and calibration. All implementation of computational strategies and algorithms required to solve the present problem was taken in IDL (Interactive Developing Language). The core of the methodology for DEM error correction and calibration intends to provide a DEM fitting to geographic space reality by calculating and incorporating error compensation surfaces generated by triangulation with linear interpolation, inverse squared distance and other flexible interpolation methods. The triangulation with linear interpolation method uses the optimal Delaunay triangulation. This algorithm creates triangles by drawing lines between data points. The original points are connected in such a way that no triangle edges are intersected by other triangles. The result is a patchwork of triangular faces over the entire extent of the grid. This method is an exact interpolator. Each triangle defines a plane over the grid nodes lying within the triangle, with the tilt and elevation of the triangle determined by the three original data points defining the triangle. All grid nodes within a given triangle are defined by the triangular surface. Because the original data are used to define the triangles, the data are honored very closely. Triangulation with linear interpolation works best when data are evenly distributed over the grid area. The inverse squared distance method is a weighted average interpolator, which can be either exact or smoothing. With inverse squared distance data are weighted during interpolation, so that the influence of one point, relative to another, declines with distance from the grid node. Normally, inverse squared distance behaves as an exact interpolator. When calculating a grid node, the weights assigned to the data points are fractions, the sum of all the weights being equal to 1.0. When a particular observation is coincident with a grid node, the distance between that observation and the grid node is 0.0, that observation is given a weight of 1.0; all other observations are given weights of 0.0. Thus, the grid node is assigned the value of the coincident observation. One of the drawbacks of inverse distance is the generation of "bull's-eyes" surrounding the observation position within the grid area. A smoothing parameter can be assigned during inverse distance to reduce the "bull's-eye" effect by smoothing the interpolated grid. Other methods such as thin-plate splines are also being implemented and tested.

The DEM calibration methodology also includes determination of global and local accuracy spatial pattern in processed DEM. The compensation surfaces for DEM calibration are calculated from comparison of original DEM data positions against corresponding known cartographic land marks. The correction surface is supposed to be DEM-added in a pixel by pixel basis. The assessment of correction efficiency is done by analyzing statistical quality data extracted from fitted DEM that provided measures of local and global DEM accuracy. Results revealed that DEM's considered in analysis, like many other currently available, have local and global errors and needs to be corrected before their uses in posterior analysis applications. Results also shown that application of proposed correction method, besides improving DEM geometric quality, also provided statistically confident numerical estimation of DEM global and local accuracy.

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