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An integrated methodology for DEM computation through the fusion of interferometric, radargrammetric and photogrammetric data

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Abstract

This paper presents a methodology for the fusion of image-based 3D informations, such as interferometric ERS data, stereoscopic (or radargrammetric) ERS data and stereoscopic (or photogrammetric) SPOT data, for Digital Elevation Model (DEM) generation.

With the availibility of several imaging sensors exhibiting high cartographic capability, the users which require a DEM of a scene, either by buying it from production companies or by generating it if they have the adequate software, are confronted with the problem of selecting both the sensor (i.e. ERS, RADARSAT, SPOT, ...) and the computational technique (stereoscopy or interferometry).

The observed scene being unique, instead of having several possible individual DEMs (i.e. ERS interferometric DEM, SPOT stereoscopic DEM, ...) as commonly found in practice, it seems natural to obtain only one single DEM whatever the number and the diversity of the available source data. The principle is to combine all the data in order to get the benefit of each of the available sensor. For exemple, the interest of combining pairs of interferometric and stereoscopic images is to provide a DEM being more operationnal in terms of the:
*** Density of reliable informations : - to get less "holes" than with the individual DEMs (stereoscopic information should provide elevation data in the holes of the interferogram and vice-versa); - stereoscopic information will help in phase unwrapping for areas of the interferogram where several rounds of 2Pi occur between two consecutive fringes.**
*** Accuracy : the availability of several measures of the elevation for a given point (several observations) should increase the accuracy of the fused DEM with respect to the individual DEMs.**

In this context, we have designed a methodology for DEM generation through the fusion of image-based 3D informations. These informations are pairs of interferometric images, pairs of stereoscopic images (radar or optical), existing DEMs and GCPs. The block diagram of the corresponding Processing Chain is shown hereafter (for ERS and SPOT data).

Processing Chain block diagram here

The Processing Chain permits to generate first the 3D informations as interferograms and parallax map respectively from the interferometric and the stereoscopic images. The Interferogram Computation Process is based on an original registration process which is fully automatic and very simple. It uses a physical warping function which is deduced from the sensor imaging geometry. By using the ERS Precise Orbit data, the physical warping function permits the registration of the pair of interferometric images automatically with enough accuracy so that the phase differences can be computed on a pixel-to-pixel basis (using a "multi- looking" process).

The 3D Fusion Process consists of computing the elevation map of the scene by means of all the available 3D informations (i.e. interferograms, parallax map, existing DEM, GCPs). A confidence criterion is set to each 3D information as the standard deviation of the error on the information (ex: the standard deviation of the error on the interferometric information is deduced from the corresponding coherence value).

The implementation of the 3D Fusion Process requires to have a single methodology in order to estimate the relief by mean of each of the individual techniques. One can show that a Bayesian formulation is the optimal framework for estimating the elevation data in a fusion approach. The relief estimation is then a bundle estimation problem where one searches for the optimal elevation which minimizes a criterion deduced from the Bayesian formulation.

All the geometric problems involved in the Processing Chain are solved by using functions based on the physical modelling of the sensors' imaging geometry, i.e.:
*** registering the interferometric and stereoscopic image pairs,**
*** moving from image coordinates to ground coodinates,**
*** relating elevation value to interferometric phase and parallax values. Note that if only interferometric data are available as input, the Processing Chain permits to generate the interferogram and the corresponding DEM (the fusion process allows phase unwrapping). In the same way, if only stereoscopic data are available as input, the Processing Chain permits to generate the parallax map and the corresponding DEM.**

The feasibility of the 3D fusion methodology has been demonstrated with ERS (SLC products) and SPOT (Panchromatic products, level 1A) images over the region of Metz (Eastern city in France) which exhibits a moderate relief (maximum height difference of 300 meters). Several DEMs have been computed using: * only the pair of interferometric ERS images with GCPs, * the pair of interferometric ERS images plus a rough DEM with GCPs, * only the pair of stereoscopic (or radargrammetric) ERS images with GCPs, * the pair of interferometric ERS images plus the pair of stereoscopic ERS images with GCPs, * only the pair of stereoscopic SPOT images with GCPs, the pair of interferometric ERS images plus the pair of stereoscopic SPOT images with GCPs.

The resulting fused DEMs have been assessed by comparison with both the individual DEMs (interferometric and stereoscopic DEMs) and a reference DEM of the test site. The results are in accordance with the expected gain of operationnality (i.e., higher density of reliable informations, better accuracy).

Keywords: