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SAR Interferometric DEM quality assessment

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Abstract

The aptitude of SAR interferometric acquisition for relief mapping has been demonstrated, and illustrated on a few test sites. Unfortunately, the validation of this mapping technique is still very limited, for three main reasons :
First, the quality assessment of each interferometric DEM is generally performed using questionable data sets, i.e. either a small number of ground control points with limited statistical representativity, or a so-called reference DEM (obtained from a SPOT stereo pair or from an official data base) which is often less accurate than the interferometric DEM itself.
Second, very few experiments have been carried out completely, i.e. including height computation and DEM geocoding. Therefore, it is difficult to predict the performances of SAR interferometry in general terms without taking into account the influence of a particular landscape (vegetation, atmosphere, slope...) or particular acquisition conditions (sensor parameters, baseline...).
Third, DEM quality assessment is often limited to a single criterion, namely, elevation standard deviation, which is very easy to evaluate. This criterion is very relevant for orthorectification but not for most DEM applications, in particular geoscientific applications. Therefore, user needs have to be expressed more clearly before a user-oriented quality assessment can be undertaken.
These limitations will be analysed in our presentation. We will propose solutions for overcoming them, based on a simulation-based concept already published (Polidori & Armand 1995) **and we will present some preliminary results.**

Keywords: SAR, interferometry, DEM, quality, errors

To overcome this problem, we have developed a validation environment dedicated to testing new algorithms or new SAR systems and to quantitatively evaluate the aptitude of existing interferometric processing chains to map relevant topographic parameters (altitude but also slope or terrain motion). The approach we use is based on artifact modelling and image simulation. Indeed, studies performed by Aerospatiale and ESGT have shown that SAR image simulation is a powerful tool for the validation of relief mapping techniques such as SAR interferometry, stereo-radargrammetry or shape- from-shading (Polidori & Armand 1995).

We have also successfully used this approach to validate other cartographic applications, e.g. change detection in radar images, building extraction from optical stereo images or spectral sensing from future MERIS data.

Simulation-based validation of radar interferometric processing (illustrated on Figure 1) has three main advantages : * it allows a great variety of situations, i.e. a variety of both SAR systems and landscapes, so that a new algorithm can be tested in many cases and not only on a particular data set ; * it can be handled in a parametric way so that the impact of any parameter on the resulting accuracy can be evaluated (by parameter we refer to both imaging parameters related to sensor, SAR processing or acquisition conditions - and landscape parameters such as slope, roughness, moisture but also atmospheric refraction index) ; * it relies on an input landscape which can be considered as an exact and dense ground truth, required to derive error maps and therefore to analyse the relationship between the behaviour of an algorithm and local terrain characteristics.

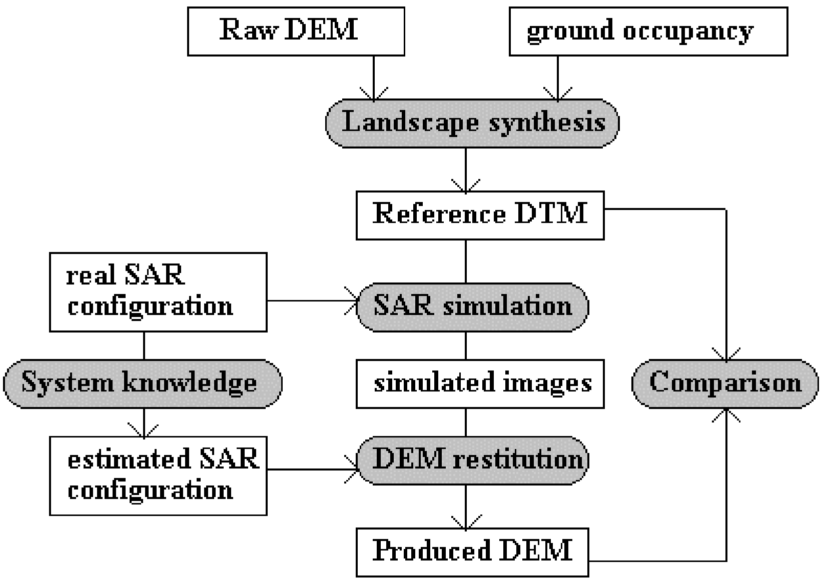

Fig. 1 : Simulation-based validation environment for radar interferometric processing.

In the case of SAR interferometry, the simulation procedure must be designed in such a way that all phase effects can be taken into account, namely : - orbit ; - platform stability ; - clock ; - atmosphere and ionosphere ; - raw signal compression and decompression ; - SAR processing ; - terrain elevation ; - terrain slope and curvature ; - roughness (i.e. spatial organization of scatterers) ; - volumetric scattering ; - subsurface penetration ; - temporal variation of ground parameters.

Since it would be very time consuming to consider all these effects in a rigorous raw signal simulator, we have implemented a simplified simulator, fully dedicated to interferometry, in which the SAR impulse response is modelled in a separate simulator.

Some results are presented in fig.2A reference map is presented in fig.2a, based on a digital elevation model and a synthetic, manually drawn land use map. Sensor parameters corresponding to the ERS case have been used. Fig.2b represents the raw interferogram obtained with a 64 meter baseline. Phase unwrapping, elevation computation and finally geocoding have led to the output map presented in fig.2c. A visual comparison of the input map and the output map is not very relevant since the data are very similar. Reversely, computing elevation differences leads to a very interesting error map (fig.2d), on which the local behaviour of our algorithms can be revealed. Error histograms can be computed, even over restricted areas, which would not be possible when validating with few unaccurate ground control points.

Fig.3 shows similar results obtained with a greater baseline (138 m). The effect of the baseline can be evaluated not only in average but also locally.

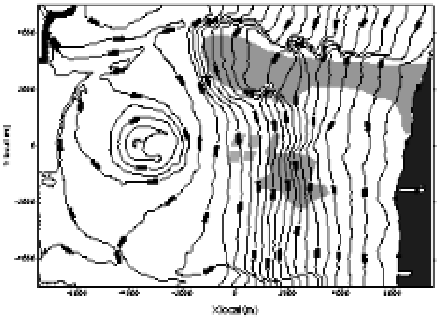

Fig.2a : input map

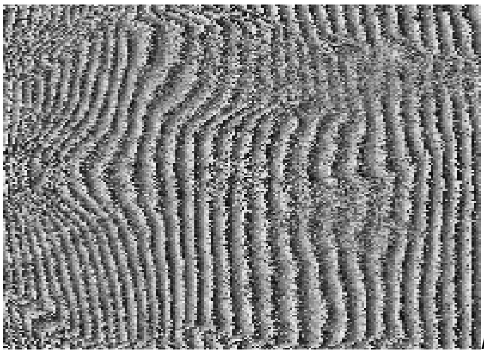

Fig.2b : raw interferogram

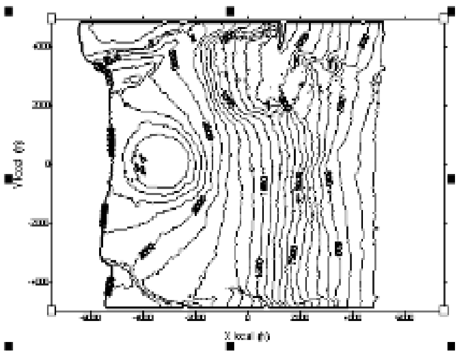

Fig.2c : output map

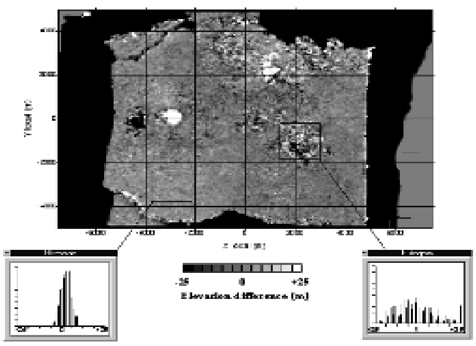

Fig.2d : error map

Fig. 2 : Results obtained for baseline = 64 m

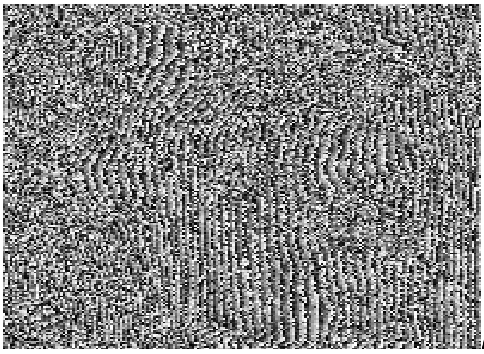

Fig.3a : raw interferogram

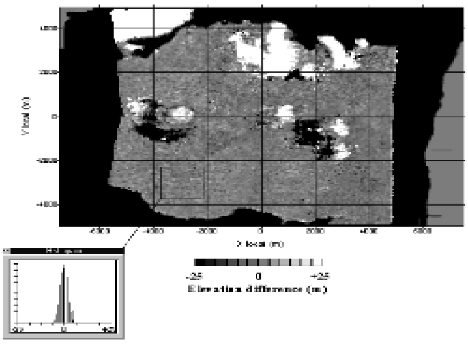

Fig.3b : error map

Fig. 3 : Results obtained with baseline = 138 m

In conclusion, a validation tool based on a dedicated image simulator is available. We use it to evaluate and improve our own interferometric processing chain, but we can propose it to other research groups who wish to evaluate the performances of their algorithms or test them in very special conditions, for instance for sensors that have not been launched yet. In a very near future, we are planning to use the same approach to validate slope mapping algorithms in the frame of the ERS tandem mission.

Reference

Polidori L. & Armand P. 1995:
On the use of SAR image simulation for the validation of topographic mapping techniques. *EARSEL, Advances in Remote Sensing*, **Vol 4, No 2**, pp. 40-48.