SAR Image Matching Using the Edge Strength Map

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***Abstract* – Based on the principle of stereovision, radargrammetry uses the parallax between a couple of SAR images to reconstruct the 3D information of the scene. In the radargrammetric process, the matching step is the most problematic one, due to speckle noise. In this paper, we present our radargrammetric chain, and then, focus on the matching module we are developing, which includes an edge detection to improve the reconstruction.**

I INTRODUCTION

Topography reconstruction is one of the possible applications of Synthetic Aperture Radar (SAR) images. To extract the 3D information three major methods exist : Interferometry, taking advantage of the instrument coherence, uses the phase difference of a couple of images to estimate the height of a point. It is a very precise technique, but it suffers from constraints on acquisition, and from several atmospheric phenomena [1]. Shape from Shading consists in evaluating the relief with a single image of a scene. Only the radiometric information, particularly shadings, permits the reconstruction. The main drawback is inefficiency in non-homogenous regions [2]. Based on the stereovision principle, radargrammetry is an automatic or semi-automatic way to generate Digital Elevation Models (DEM) using a couple of SAR images. It uses the parallax information between images to compute a disparity map. Radargrammetry is equivalent to the method developed in optics, and has a growing interest, due to the increasing amount of stereoscopic couples we can obtain with new sensors, and to the robustness this method seems to offer [3].

In this paper, we deals with radargrammetry. Processing chain includes geometric modelling, epipolar deformation, image matching and space triangulation. We are particularly interested in image matching, which is the most important and difficult step in the chain : for each pixel in the first image, the matching module tries to find its homologous point in the other image. Two main matching techniques exist : Area-based matching techniques measure correlation among reflectivity of pixels in two area patches. But the presence of speckle noise makes the interpretation of the measure ambiguous, and the maximum of correlation is not necessarily associated with the correct homologous point. Feature-based methods do not consider the pixel grey values as a primitive to correlate, but extract other structural information (edges, linear structures, regions, texture …). They give more robust correspondence points but do not generate dense disparity maps which are used to compute the 3D reconstruction.

Section II of this paper presents briefly our radargrammetric chain. Section III focus on the matching step, presenting first a coarse-to-fine matching method, and then a way to integrate edge strength map to improve the results. Finally, we conclude with perspectives in SAR image matching.

II THE RADARGRAMMETRIC CHAIN

Our radargrammetric processing chain is shown in Fig 1. We start with a couple of Single Look Complex (SLC) images and all related data (sensor parameters, ephemerides,…). Final product is a DEM in a specified geographic coordinates system.

Using information about the images acquisition, the objective of Geometric Modelling is to tie images to the terrain. Direct and inverse localization can be computed to link image points to geographic points.

Then, resampling in epipolar geometry is performed. The interest is to limit the size of the space search of homologous point. Search can be reduce to almost one dimension. The existence of epipolar lines has been demonstrated in SAR and optics spatial imagery [4].

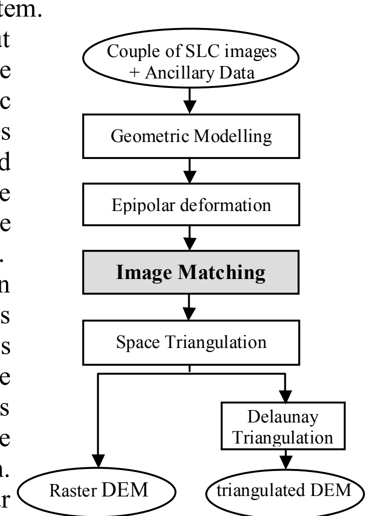


Fig.1. Radargrammetric Chain

The image matching step, which produces a disparity map, will be presented in the next section.

Given the disparity map and the inverse deformation epipolar model, we can identify homologous points in original images (before the epipolar transformation). Thus, by means of a space triangulation process and using the known viewing parameters, we compute the 3D dimensional position of each point.

Finally, due to inverse epipolar resampling, relief distortions, and unmatched points, the set of points generated from the 3D reconstruction forms an irregular DEM. So we organise them in a network of Delaunay triangles [5].

III THE MATCHING STEP

As said in the introduction, the matching step is the most difficult, but also the most important because it determines the quality of the 3D reconstruction. The first point of this section is about a classical coarse-to-fine method we have evaluated with SAR images. Then we present the edge detection problem in SAR images, and the way to use this information to improve the matching quality.

A. Coarse-to-Fine Matching Method

Lot of authors propose coarse-to-fine algorithms for matching problems. It improves results in terms of computation time and robustness. In SAR imagery it also leads to reduce the speckle influence.

Starting with the lower resolution by averaging , our algorithm checks for each point the cross-correlation, computing two standard 2D correlation. If the cross-correlation is not validated the point is rejected. After a Delaunay triangulation, linear or cubic interpolation is led to complete the disparity map. This map is then used to bound the search space at the upper resolution. Continuity of matching is ensured and it leads to a good estimation of the relief of the scene (Fig.2).

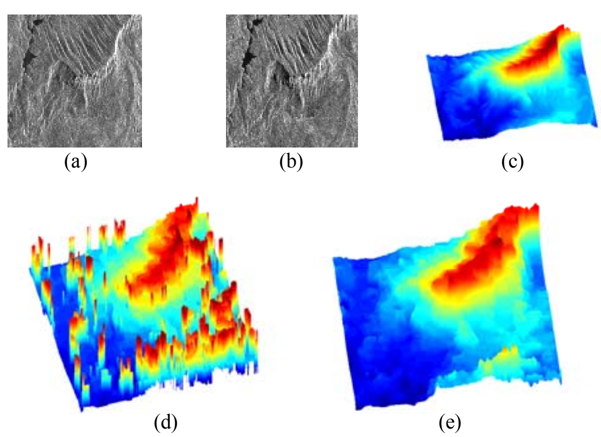


Fig.2. (a) and (b) : RADARSAT images in epipolar geometry . (c) : 3D view of the reference disparity map, (d) : Classical matching method, (e) : Coarse-to-fine method.

Analyzing these results, two major problems are raised : the first one is an important smoothing, especially on multiple edge areas, which often correspond to surface discontinuities. The second one is matching errors in large homogenous regions. To improve this disparity map, we propose, in the first case, to include edge information by an adapted edge strength map, and in the second type of problem, to adapt the correlation window size.

B. Edge Detection in SAR Images

Edge detection and extraction in SAR images are difficult tasks. Classical techniques, derived from optical imagery, are based on an approximation of the gradient. An edge pixel is usually considered as a local gradient maximum in the gradient direction, or a second derivative zero-crossing in the same direction [6]. These operators are not adapted to SAR imagery because their False Alarm Ratio (FAR) depends on the radiometry [7] (Fig .3), which makes impossible a good post-processing (thresholding, edge extraction,…). Adaptations have been proposed (log transformation, normalization) to have a Constant False Alarm Ratio (CFAR), but considering an edge as a maximum of the first derivative is not adapted to the multiplicative nature of the speckle noise.

In SAR image processing, Ratio of Average (ROA) operators are usually chosen. Fjørtoft and al. propose a Ratio of Exponentially Weighted Averages (ROEWA), and show in [8] that it is an optimal tradeoff between localization precision and speckle reduction when the reflectivity jumps follow a Poisson distribution. ROEWA is the operator we use to include edge information in our matching strategy.

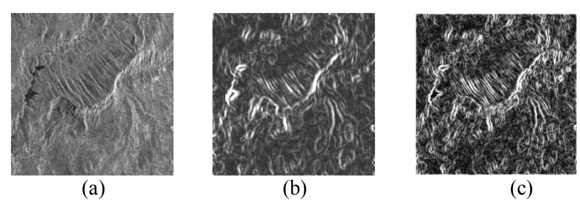


Fig.3. (a) SAR image, (b) ROEWA operator, (c) Deriche Operator

C. Matching Using the Edge Strength Map

In [9], Paillou and Gelautz propose to use an edge detector, the "optimal gradient" in the matching method. In this perspective, we applied our coarse-to-fine method to ROEWA images of our epipolar pair. Results were not satisfactory so far : on large homogenous regions without edges, disparity diverges, due to error propagation in the multi-resolution algorithm. On surface discontinuities, which often correspond to edges, it does not improve localization of homologous.

So we propose to take advantage of the edge information implementing another strategy. The multi-resolution principle is kept. As a pre-matching step, we compute a detection of areas containing edges (i.e. surface discontinuities) (Fig. 4), convoluting and thresholding the ROEWA edge strength map of the left epipolar image (master). Then, on each level, we adapt 2 parameters, considering if we are in an edge-area or not :

- in edge-areas, the correlation window size is reduced, to improve localization of pixels, and the continuity constraint is slackened between resolution levels.
- in others regions, correlation window size and continuity constraint are maintained.

The architecture of the matching module is shown Fig. 5.

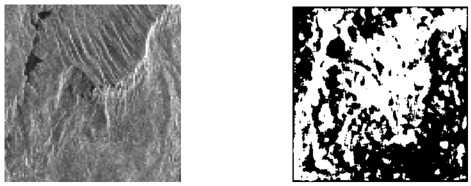


Fig.4. Epipolar Image and Detection of Edge-Area (in white).

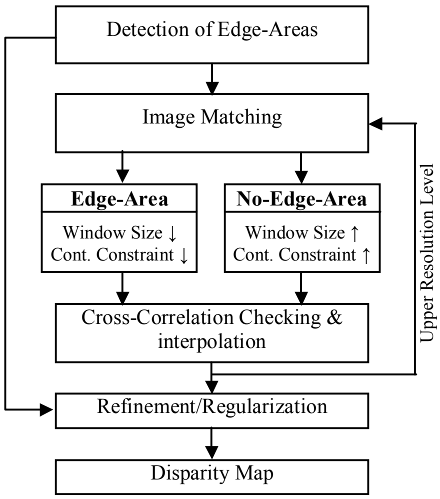
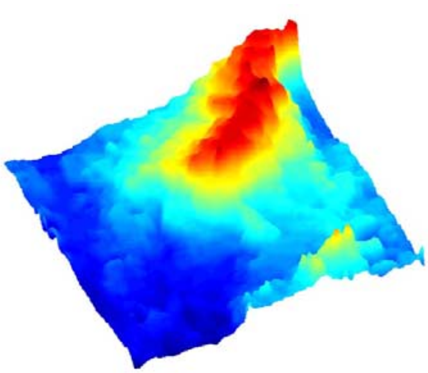


Fig.5. Matching Module.

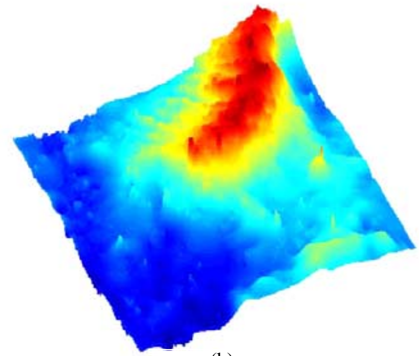
- *Results*

The computed disparity map is presented on Fig. 6. This method offers the advantage to improve regularity in low relief variations zones, without losing details on surface discontinuities. On the mountain crests, details are not only preserved but also improved, comparing to the standard coarse-to-fine algorithm. Gain of continuity is obvious on the other parts of the map.

This matching method requires various parameters to be adjusted : edge areas detection threshold, resolutions levels, correlation window sizes, continuity constraint. The next step of work consists in refining this parameterization, in order to increase the disparity map quality, and quantifying precisely the improvement.



(a)



(b)

Fig. 6. Computed Disparity Maps (a):Standard Coarse-to-fine Method, (b) Using the Edge Strength Map Method

IV CONCLUSIONS & PERSPECTIVES

SAR image matching in radargrammetric conditions is a difficult problem. To improve results, it is necessary to have an adapted matching strategy, but also to include as much a priori information as possible. The coarse-to-fine strategy seems necessary to obtain a good regularity of the disparity map. A variable windows size and the insertion of the edge strength map information improves the results.

To go further, we are still working on edge extraction in SAR images, to be able to extract thin edges and to match them. A new estimation of the correlation, specific to SAR images (including phase and amplitude signals), is also under development.

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