GCPs Selection from Multi-source Data
Over Mountainous Topography

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GCP selection in mountainous relief is a difficult process. This paper shows methods using topographic, SAR and visible image data to define ridge points as GCPs. SAR layover and shadow boundaries method is the best method but it depends of the back and fore slopes versus the look angle. Using SPOT ortho-image the results depend mainly on the visibility of the feature between the SAR and visible images. Simulated SAR is not a good solution since the DEM induces too large planimetric errors.

INTRODUCTION

Data fusion is a key point in most of the applications of remote sensing and geographic system. The processing of the multi-sensor data can be based on the concept of "geocoding image", to a term originally defined in Canada in defining value-added products. However, the term "ortho-image" is now much preferred in referring to a unit of geocoded data. To integrate different data under this concept, each raw image must be separately converted to an ortho-image so that each component ortho-image of the data set is registered pixel by pixel, and the different radiometries can then be combined.

The ortho-image generation requires precise geometric processing adapted to the nature of the data to define the deformation functions between the image geometry and the terrain geometry, and using a more and less number of ground control points (GCPs). There are always difficulties of finding GCPs between images, because they are imaged differently by sensors having highly variable geometry and responses to illumination. These difficulties are enhanced in mountainous topography. Furthermore identifiable features on image are not always indicated on the maps.

The objectives of this paper is then to focus on different methods to select GCPs from multi-sensor data, (RADARSAT and SPOT), and from cartographic data (digital elevation model and topographic maps). The methods use the different geometric and radiometric characteristics of the sensors (radar and visible), but also the physical characteristics of the terrain and its relief. It includes the radiometric disparities of the radar foreslope and backslope, the simulation of radar data, the use of stereoscopy and the complementarity of radar and visible images.

GCPS SELECTION METHODS

Four methods for the GCPs selection in the RADARSAT images are developed taking into account the different characteristics of the data:

- with ridge points in the mountains using the paper maps coordinates (Fig. 1 and 2);
- with common features using the SPOT ortho-image (Fig. 3);
- with ridges using simulated SAR images generated from the DEM and a simple relief induced backscatering (Fig. 4);
- with two images using stereoscopy.

Previous research on the use of layover and shadows as feature for GCPs was carried out [1, 2]. They did not consider that the ridge of a mountain is not always the layover/shadow boundary (Fig. 1). Only in Fig. 2, the ridge is well imaged and located at the back and fore slopes boundary: it then depends on the SAR look angles versus the fore- and back-slopes. The map is thus used to compute approximately the slopes at these ridge points.
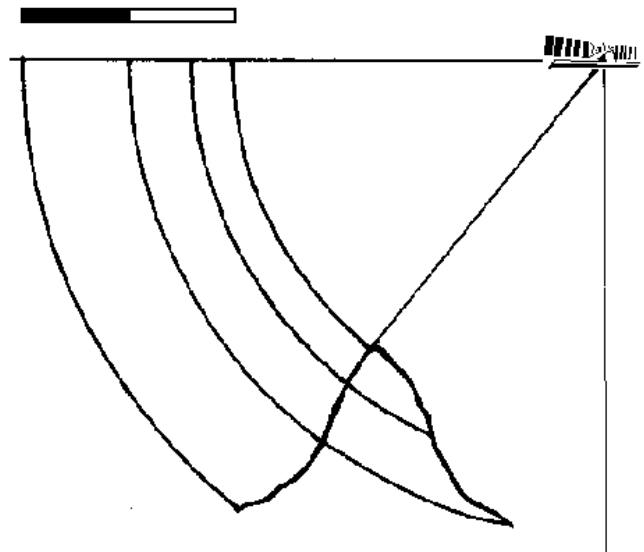

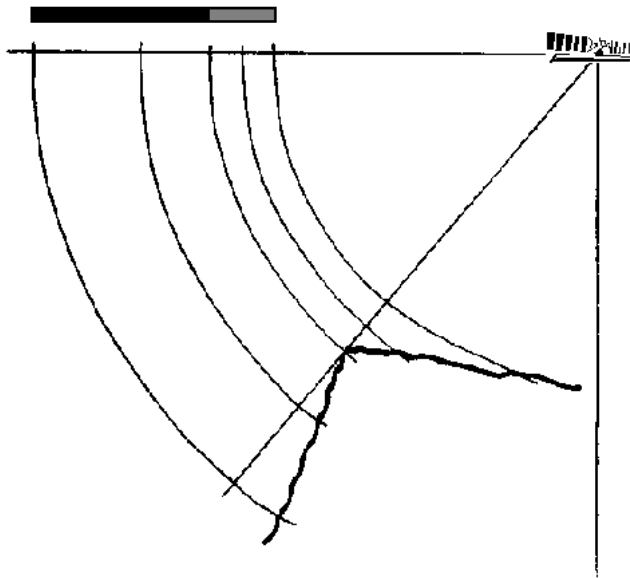Fig. 1. Ridge point in mountain relief as a "bad" GCP

Fig. 2. Ridge point in mountain relief as a "good" GCP

Fig. 3 is an example of the difference in geometry and radiometry between two sensor images. However, common features (mainly ridges) are visible on both images. The accuracy of the cartographic coordinates extracted on the SPOT ortho-image will depend on the DEM accuracy [3]. The maximun elevation scaling factor for SPOT is 0.6: in our study the 80-m elevation error in the highlands is thus translated into 12-m planimetric error in the ortho-image.
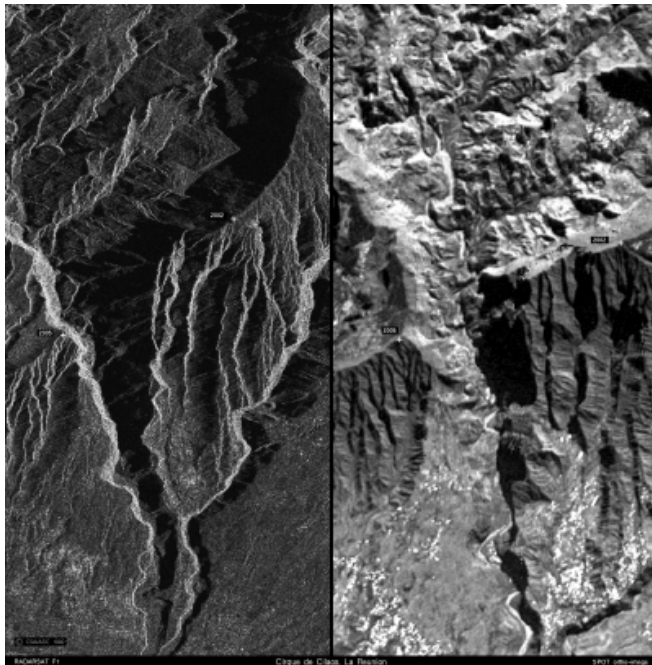

Fig. 3. Ridge points common to RADARSAT and SPOT

Fig. 4 is an example of ridge and valley points common to RADARSAT and simulated SAR. Since the DEM is used to create the simulated SAR, some shapes are distorted when compared to the RADARSAT image. The elevation scaling factor is 1 to 1.5 for the F1 and F3 RADARSAT data [4]. Consequently, the 80-m elevation error in the highlands is translated into 80-to-120-m planimetric error in the simulated SAR image, while the 20-m elevation error in the lowlands is translated into a 20-30 m planimetric error.
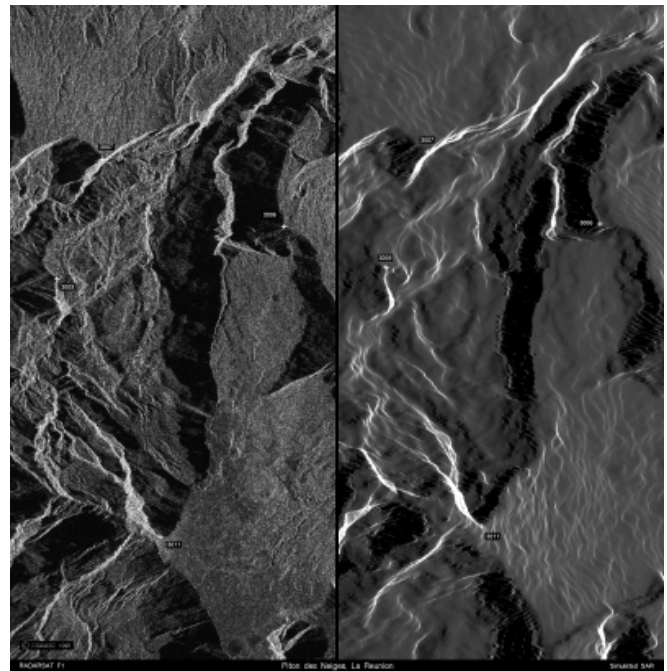

Fig. 4. Ridge points common to RADARSAT and simulated SAR images

STUDY SITE AND DATA SET

The study site is the Reunion Island located in the Indian Ocean. It is a rugged topography of an active volcanic terrain highly dissected by a humid tropical climate generating steep cliffs and deep gorges (100 to 1 000 m) for the creekbeds.

The remote sensing data consist of:
- two RADARSAT fine beam scenes (F1, F3) acquired October 6 and 13, 1996, respectively from descending orbits; and
- a SPOT panchromatic ortho-image acquired May 31st, 1996 with a 20-m pixel spacing.

The RADARSAT beam modes F1, F3, F4 have approximate viewing angles ranging from 37º, 41º, and 43º in the near range to 40º, 44º, and 46º in the far range, respectively. The data were processed at the Canadian Data Processing Facility

[5], and the resulting product is an image in ground range, with a pixel spacing of approximately 6.25 m in range by 6.25 m in azimuth, and oriented along the satellite track. For the data acquired from a descending orbit, the illumination direction is approximately from the East to the West.

The cartographic data include:
- topographic maps at a scale of 1:25,000; and
- a DEM with a grid spacing of 40 m, generated by the French company ISTAR in 1992 using a stereoscopic processing of two SPOT panchromatic images. The accuracy is evaluated to be 20 m in the lowlands and 80 m in the highlands. The elevation varies from 0 to 3070 m. The area covered is 88 km by 73 km.

RESULTS AND DISCUSSION

To test the GCPs and the effect on the RADARSAT geocoding the collinearity condition modelling developed at CCRS is used [3]. Based on principles related to orbitography, photogrammetry, geodesy and cartography this method reflects the physical reality of the complete viewing geometry and the distortions that may occur during the image formation. Previous research has demonstrated that the GCPs residuals on the bundle adjustment are mainly dependent of their accuracy.

Table I is a summary of the GCP residuals in X and Y for both RADARSAT fine mode images as a function of the GCP selection method. The first method uses only well defined map points as a reference.

Table I. GCP residuals function of the selection method

GCP Collection	Number of GCPs	Residuals on F1 Image X	Y	Residuals on F3 Image X	Y
Map	24	12m	8m	17m	15m
Map + ridge points	28	18m	10m	19m	21m
Map + ortho-SPOT	28	11m	12m	27m	20m
Map + sim. SAR	33	31m	19m	25m	28m

The method using the map ridge points as defined in Fig. 2 gives consistent results for both images. They show very well the applicability of the method as soon as the geometry of the ridge point enables an exact relationship between the ground and the image.
The third method with SPOT ortho-image gives different results for the two images. In the F1 image, the ridge points

were better defined between the two images, and they also were located at a lower elevation. The DEM induced planimetric error is less in the ortho-image.

The simulated SAR images gives the worse results since large planimetric errors resulted from the DEM in the generation of the simulation. This method should not be used when no precise DEM is available. Since there is no texture related to the land cover backscatter in the simulated image almost no feature other than ridge point are available.

CONCLUSIONS

This paper shows methods to acquire GCPs on SAR images for their rectification and fusion with other data. It used a CCRS developed geometric correction modelling to test the methods with the GCPs residuals of the bundle adjustment.

SAR layover and shadow have been used as GCP features. Only a specific geometric configuration with shadow in the back slope and no layover in the fore slope enables an exact relationship between the terrain and the image.

The method using the SPOT ortho-image shows also good results. The accuracy is mainly dependent on the feature visibility between the SAR and SPOT images, and the DEM accuracy which induced a planimetric error.

The method using a simulated SAR image is the worse due mainly to the error propagation of the DEM, and to the lack of texture. It should not be used without precise DEM.

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