SAR Geocoding and Multi-Sensor Image Registration

Charles Werner, Tazio Strozzi, Urs Wegmüller, Andreas Wiesmann
Gamma Remote Sensing AG
Thunstrasse 130, CH-3074 Muri b. Bern, Switzerland
Tel: +41 31 951 70 05, Fax: +41 31 951 70 08, email: cw@gamma-rs.ch

***Abstract*—Quantitative analyses of remote sensing data acquired with variable geometries and different sensors are greatly facilitated by geocoding the data to a common geographical reference. Errors in geocoded SAR images are due to inaccuracies in the orbit data, errors in the processing parameters, and DEM errors. Automated terrain geocoding of SAR data is possible using only a single resampling of the native slant-range to the final map geometry after measurement and correction for residual geolocation errors. An accurate adaptive resampling algorithm for the interpolation from the SAR geometry to the map coordinate system is presented. This processing paradigm has been extended to permit combining data from different SAR instruments.**

I. INTRODUCTION

Geo-referencing of SAR data is essential since most applications require localization of features within the image. Referencing data to a common coordinate system permits analysis of data taken using different sensors and imaging geometries. It also permits combining SAR data with other raster and vector format data. The natural SAR image coordinates are determined by the along-track position of the sensor, slant range, and Doppler processing parameters. Geographic map coordinates are specified in terms of the projection parameters, ellipsoid, and datum. SAR geocoding is the transformation of data in SAR coordinates into an orthogonal geographic map projection.

The inverse operation, where a data set in a map projection is transformed into radar coordinates is used for geocoding refinement and in differential interferometry [1]. The geocoding system described here accurately and efficiently performs both transformations.

II. SAR GEOCODING

Our SAR geocoding approach uses the satellite orbit, local terrain information, and SAR image processing parameters to calculate a lookup table that gives the SAR image coordinates for each point in the geocoded image geometry. The geographic coordinates can either be latitude and longitude, or the northing and easting of a particular map projection. This mapping is unique in the sense that every point in the map coordinates corresponds to unique range and azimuth SAR image coordinates. The inverse transformation is not unique because SAR image layover causes a single point in the radar image to map to several points in the map projection coordinates.

Calculation of the lookup table requires a digital elevation model (DEM) as input. The DEM is resampled first into the desired output projection and sample spacing. The precise slant range and sensor along-track positions are then calculated for every point of the resampled DEM coordinates.

Errors in geocoded SAR images are due to inaccuracies in the orbit data, errors in the processing parameters, and DEM errors. These errors can be reduced through refinement of the look-up table using the known locations of recognizable image features. These ground control points have traditionally been selected manually, a tedious and error prone process. The very different appearance of SAR images and speckle noise introduce significant uncertainty. Furthermore, many of the targets that can be identified, such as buildings and trees should not be used because of the effect of the target height on the position in the SAR image.

In our automated system, ground control information is obtained by use of a simulated SAR backscatter image derived from a pre-existing DEM. The SAR backscatter is determined from the local geometry and resampled into the SAR coordinates using inverse geocoding [2]. Rather than having a small set of points, the simulated image can provide hundreds of features suitable for automated matching. The local offsets between the simulated and actual images are measured throughout the image. Then a least-squares fit of the offsets is performed to obtain a polynomial transformation used to refine the lookup table. The values in the refined lookup table give the precise mapping between the SAR image and DEM. The output geocoded image is obtained using nearest neighbor, spline, or bilinear interpolation methods. Modification of the lookup table values avoids having to resample the data a second time when generating a precise geocoded image. A block diagram of the geocoding system is shown in Fig 1.

Transforming the simulated radar backscatter image (in DEM coordinates) into the SAR range-Doppler coordinates requires resampling over a non-uniform grid. An adaptive interpolation algorithm is used that locates the known data values in the vicinity of the desired output point. A distance ordered search about each output point is performed to locate interpolation values. The search is continued until a specified number of data values have been accumulated. These values are weighted and summed. The weights are function of distance from the known point to the desired output location. Patching of the output data can be implemented for resampling of very large images.

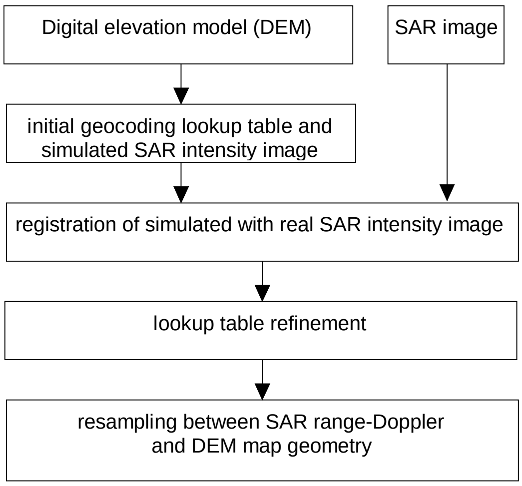

Fig. 1: Flow chart of automated terrain corrected SAR geocoding.

III. Multi-Sensor Data Analysis

Quantitative multi-sensor data analysis requires that the data are in a common geometry. It is especially important for change detection that the images are accurately coregistered. For example, a land use map coming from an optical sensor can be combined with a SAR derived change detection map.

Initially data sources from different sensors are brought into a common map projection. The transformed data are then precisely coregistered to a reference scene using a correlation-matching algorithm.

One of the main advantages of the ENVISAT is the ability to image using a set range of look-angles between 20 and 50 degrees. Consequently, data for a particular site may contain several different incidence angles. The incidence angle dependence of the backscatter is source of information useful for surface classification. These data can be analyzed as set by transformation to a common map projection.

The following experiment was performed using ERS data acquired near Bern, Switzerland. This scene has regions of both level and rugged terrain. This image was geocoded first using only the ellipsoid and then using a DEM to correct for terrain effects. These images were combined as shown in Fig. 2 demonstrating the importance of local terrain height in the geocoding. Errors in the height result cause position errors for ERS that are 2.4 times greater. This result underscores the necessity for using the best DEM available for geocoding. In the worst case, a global DEM with maximum height error on the order of 100 meters can be used [3].

The ability to coregister images acquired using different ENVISAT ASAR modes was also investigated. Data over the Bern region from overlapping adjacent ERS swaths were individually geocoded using a DEM. The uniform light cyan hue in the mountains indicates excellent coregistration and suggests a systematic change in backscatter over the time interval between tracks.

As a further improvement in the processing strategy, especially useful when using a low resolution DEM data is to use one of the SAR images as a reference for matching rather than the simulated backscatter derived using topography alone. Typically there are significantly more matching features available in the actual image than in the simulated backscatter image derived from the topography.

A second example of geocoding is shown in Fig. 3 where data from both ascending and descending ERS passes are combined. These data bracket a flooding event that occurred in early 1999 in Bern [6]. The ability to combine data from ascending and descending orbits is especially important for rapid access and monitoring of natural disasters. Furthermore, combining data from ascending and descending passes fills in most of the gaps in maps due to layover and shadow in areas of high relief.

A third geocoding example shows coregistration of images from JERS and ERS. In this case, the Tandem interferometric coherence from ERS has been used as the red channel. In this case the input data had different frequencies, aspect angle, and sample spacing. Offsets between the JERS and ERS images in a common map projection were used to refine the coregistration by modifying the lookup table.

Coregistration of data from different sensors is extremely useful for a number of reasons. The range of parameters is greatly expanded (wavelength, polarization, aspect angle, time) that can be incorporated into the analysis of a particular scene. Furthermore, long term studies of an area can be extended to far exceed the life of a single sensor. This approach has been extended to include geocoded optical data as a reference scene [5].

IV. Conclusions

A method for SAR geocoding and multi-sensor image registration was presented. It consists of three main elements: transformation of the data to a common image geometry (typically a map projection), offset refinement using automated image matching, and image transformation in a single step. This method is accurate and functions well with data from different SAR instruments. An experiment using data from ERS-2 demonstrates the ability to accurately coregister data ENVISAT ASAR data of different image modes.

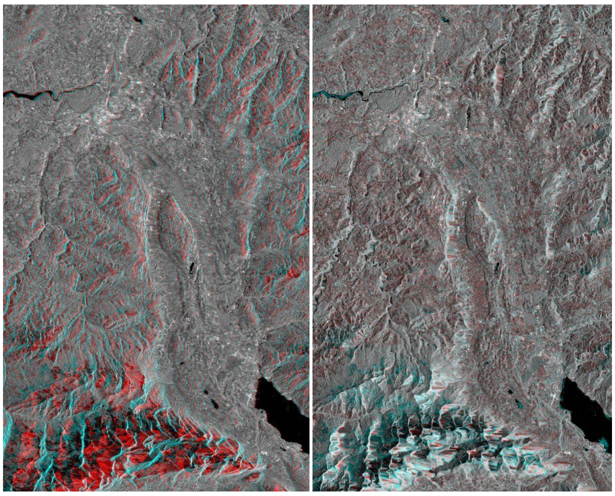

Fig. 2. Region near Bern, Switzerland. In each case, two images have been superposed as red and cyan. For the image on the left a single scene was geocoded first using only an ellipsoid and then including terrain height. Large discrepancies are visible at the bottom of the image. For the image on the right, adjacent ERS swaths (orbits 20918 and 21190) were geocoded using a DEM simulating ASAR data acquired with different look angles.

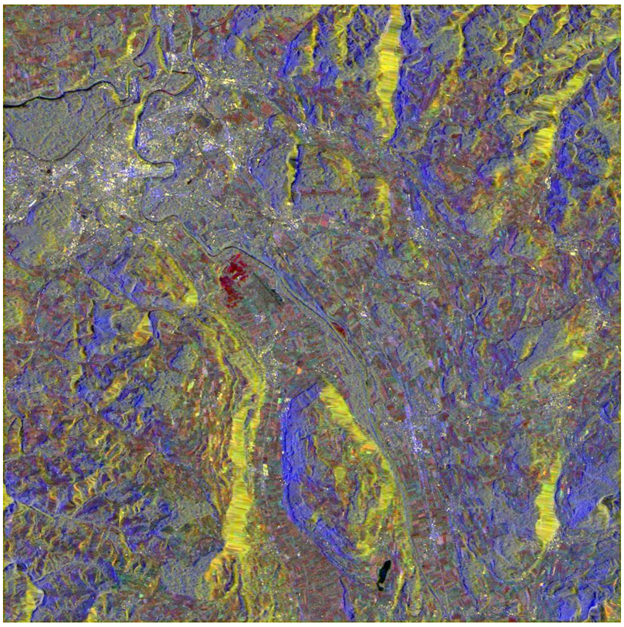

Fig 3. Multi-temporal combination of ascending and descending orbit ERS data for flood mapping. red: descending 21-Apr-1999, green: descending 26-May-1999, blue: ascending: 26-May-1999.

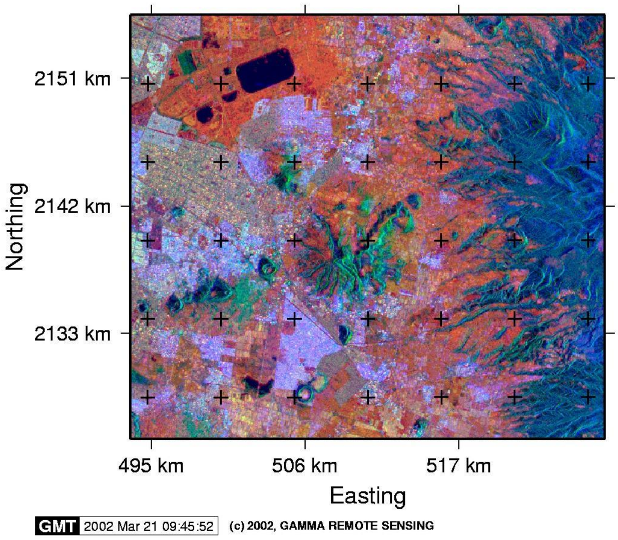

Fig. 4. Mexico City (UTM zone 14). Color composite of ERS Tandem coherence intensity (red), ERS backscatter (green), and JERS backscatter (blue).

V. References

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