PEER-REVIEWED ARTICLE

REMOTE SENSING BRIEF

An Earth Remote Sensing Satellite-1 Synthetic Aperture Radar Mosaic of the Tanana River Basin in Alaska

Abstract

Because the pixel location in a line of Synthetic Aperture Radar (SAR) image data is directly related to the distance the pixel is from the radar, terrain elevations cause large displacement errors in the geo-referenced location of the pixel. This is especially true for radar systems with small angles between the nadir and look vectors. Thus, to geo-register a SAR image accurately, the terrain of the area must be taken into account. (Curlander et al., *1987; Kwok* et al., *1987, Schreier* et al., *1990; Wivell* et al., *1992). As part of the 1992 National Aeronautics and Space Administration's Earth Observing System Version 0 activities, a prototype SAR geocoding and terrain correction system was developed at the U.S. Geological Survey's (USGS) EROS Data Center (EDC) in Sioux Falls, South Dakota. Using this system with 3-arc-second digital elevation models (DEMs) mosaicked at the EDC Alaska Field Office, 21 ERS-1 SAR scenes acquired at the Alaska SAR Facility were automatically geocoded, terrain corrected, and mosaicked. The geo-registered scenes were mosaicked using a simple concatenation.*

Satellite and Earth Model Algorithm

The algorithm developed at the EDC uses a latitude, longitude, and elevation from a DEM to calculate a line and sample location in the SAR image. This is accomplished by solving the Doppler shift equation, which relates the relative velocity between the point on the Earth and the satellite to the measured frequency shift of the returned radar pulse (Curlander *et al.*, 1982; Roth *et al.*, 1989; Wivell *et al.*, 1992). The EDC algorithm uses a time-dependent satellite model and a time-dependent Earth model and incorporates these models into the Doppler shift equation. This results in the Doppler shift equation being dependent only on time. The equation can then be solved efficiently using a Newton-Raphson iteration on the time variable.

Ephemeris and Model Correction

Due to small errors in the ephemeris, in the satellite model, and in the Earth model, a geocoding procedure using the ephemeris and these models alone will result in a slightly inaccurate registration. These errors can be reduced by constructing a simulation of the SAR image to be used as a reference (Curlander, 1991; Leberl, 1990; Wivell *et al.*, 1992). The simulation is created by using the ephemeris data as input to the satellite model and by using the DEM information for a given location as input to the Earth model. The resulting solution of the Doppler shift equation produces a line and a sample location in the SAR image. A backscatter value is calculated using a simple backscatter model (Leberl, 1990) for this SAR image location. This backscatter value is stored at the calculated line and sample location in an output array. This process is repeated for each location in the DEM.

The simulated image emulates the distortions due to terrain, such as the sharp contrast between the bright SAR-facing sides of the mountains and the dark flats and the still darker sides of the mountains facing away from the SAR. Because the simulated image is in the same satellite projection as the SAR image, the errors in the ephemeris and in the models are easily related to the displacement errors between the simulated image and the SAR image. To find the displacement errors between the images, a computer generated grid of points corresponding to image locations is used to match the simulated image and the SAR image. This matching process is automated using normalized cross correlation and a matched-point editor based on the method of least squares. The displacement errors are then fit to one-degree error planes for both the line and sample errors. These planes are used to correct the line and sample output of the model.

Mosaicking

The geocoding and terrain correction algorithm was incorporated into EDC's image processing system, the Land Analysis System (LAS) (Ailts *et al.*, 1990). The LAS creates a data descriptor record (DDR). This record contains information about the map projection used, such as the type of map projection, the projection coordinates of the image corners, and the physical pixel size. Because the DEM is used as the output reference space, the resulting terrain-corrected SAR image is registered to the DEM. The mosaic was created using a LAS function called CONCAT. This routine uses the DDR to calculate where to lay a projected image over previously projected images. The resulting mosaic is shown on the cover of this issue of *PE&RS*. No radiometric smoothing has been done be-

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tween the scenes and no manual shifting was done to the individual scenes.

Description of the Mosaic

The mosaic consists of 21 individual geocoded and terrain corrected ERS-1 SAR scenes of a portion of the area of the Tanana River Basin in the interior of Alaska. The individual scenes were mosaicked using a simple concatenation without any radiometric edge smoothing or manual shifting of the images. The pixel size for each of the 21 images is 90 metres by 90 metres to match the resolution of the DEM, down from the 12.5- by 12.5-metre pixels in the original standard SAR product. The resolution of the standard four-look SAR product is approximately 25 metres. The final mosaic contains 4,754 lines by 5,800 samples, which results in an area of about 225,000 square kilometres. Fairbanks, Alaska, is approximately in the center of the mosaic. The large bright areas, such as the one southwest of Fairbanks, are areas of recent forest fires. In most cases the seams between images are invisible. One noticeable seam running north to south (just west of Fairbanks) is believed to be due to a difference in the amount of surface moisture present between the two orbital passes. The far southwest scene contains Mt. McKinley. Notice in the Mt. McKinley scene, the edge of the scene has been greatly warped due to the terrain correction process over this area of large elevation change.

References

Ailts, B., D. Akkerman, B. Quirk, and D. Steinwand, 1990. LAS 5.0—An image processing system for research and production environments, 1990 ACSM-ASPRS Annual Convention, Technical Papers, Denver, Colorado, March, Vol. 4, pp. 1–12.

Curlander, J. C., and R. N. McDonough, 1991. *Synthetic Aperature Radar, Systems and Signal Processing,* John Wiley and Sons, New York.

Curlander, J. C., R. Kwok, and S. B. Pang, 1987. A post-processing system for automated rectification and registration of spaceborne SAR imagery, *Int. J. Remote Sensing,* Vol. 8, pp. 621–638.

Curlander, J. C., 1982. Location of spaceborne SAR imagery, *IEEE Trans. Geosci. and Remote Sensing,* Vol. 20, pp. 359–364.

Kwok, R., J. C. Curlander, and S. B. Pang, 1987. Rectification of terrain induced distortions in radar imagery, *Photogrammetric Engineering & Remote Sensing,* Vol. 53, pp. 507–513.

Leberl, F. W., 1990. *Radargrammetric Image Processing,* Artech House, Inc., Norwood, Massachusetts.

Roth, A., H. Craubner, and Th. Bayer, 1989. Prototype SAR geocoding algorithms for ERS-1 and SIR-C/X images, *Proc. IGARSS* (Vancouver, Canada), Vol. 2, pp. 604–607.

Schreier, G., D. Kosmann, and A. Roth, 1990. Design aspects and implementation of a system for geocoding satellite SAR-images, *ISPRS J. Photogrammetry and Remote Sensing,* Vol. 45, pp. 1–16.

Wivell, C. E., D. R. Steinwand, D. J. Meyer, and G. G. Kelly, 1992. The evaluation of digital elevation models for geocoding synthetic aperture radar images, *IEEE Trans. Geosci. and Remote Sensing* (in press).