Extraction of Ground Control Point (GCP) from SAR Image

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Abstract: A ground control point (GCP) is a point on the surface of Earth where image coordinates and map coordinates can be identified. The GCP is useful for the geometric correction of systematic and unsystematic errors usually contained in a remotely sensed data. Especially in case of synthetic aperture radar (SAR) data, it has serious geometric distortions caused by inherent side looking geometry. In addition, SAR images are usually severely corrupted by speckle noises so that it is difficult to identify ground control points. We developed a ground point extraction algorithm that has an improved capability. An application of radargrammetry to Daejon area in Korea was studied to acquire the geometric information. For the ground control point extraction algorithm, an ERS SAR data with precise Delft orbit information and rough digital elevation model (DEM) were used. We analyze the accuracy of the results from our algorithm by using digital map and GPS survey data.

Keywords: SAR, Ground control point, Extraction

1. Introduction

The image product from imaging remote sensors can be regarded as a map with relatively high resolution and scale accuracy [1]. Since the remotely sensed data usually contained systematic and unsystematic errors, the geolocation, i.e. determining the location of the image in geographic coordinates, is required. For optical sensors, the geolocation can be accomplished by tie-pointing or ground control pointing which is selecting GCP image coordinate with their map coordinate counterparts in previously mapped regions. In case of SAR image, the tie-pointing is significantly difficult due to obscured image, unmapped region, etc. Especially SAR data have serious geometric distortions caused by inherent side looking geometry and are usually severely corrupted by speckle noises.

Meanwhile, SAR has an advantage over optic seonsors. SAR is an active radar system with information on the range to the target and the Doppler history of the returned signal, the location of the pixel in a given image can be derived from knowledge of the sensor position and velocity [1-2].

We developed the ground control point extraction algorithm using ERS SAR image with precise Delft orbit information and digital elevation model (DEM). The extraction algorithm was tested in Daejon area, Korea.

2. Data Processing

We computed the amplitude image from an ESA ERS-1 SAR single-look complex data acquired on January 22, 1996, and generated the interpolated USGS GTOPO-30 DEM data with available planimetric resolution. For the accuracy analysis of extracted GCPs, eleven tiepoints are selected from the SAR image and the digital map. They were then converted to comparable map coordinates.

3. Geolocation Algorithm

Referring to Fig. 1, the target position(P) is related to the range(R) from sensor position and velocity(m). Since the SAR image has the Doppler history of the signal, it is possible to solve the earth location for each image pixel. We use the two geolocation algorithms: the one is conventional, and the other is the hybrid algorithm using radar image simulation.

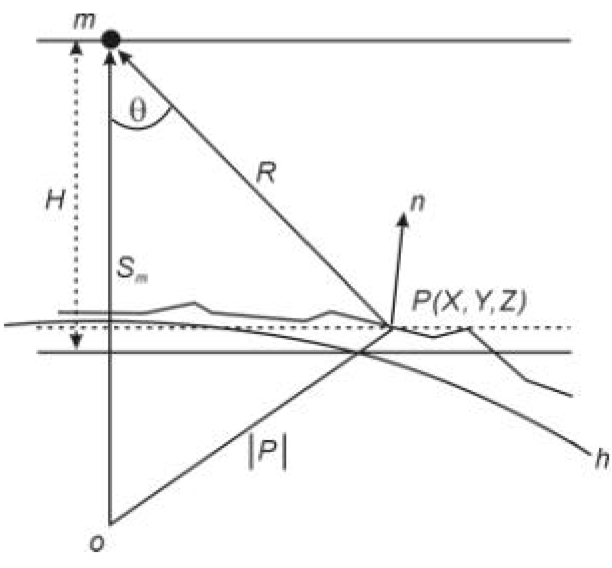

Fig. 1. Radar Geometry for the Geolocation Algorithm.

1) Image to Cartesian Coordinates Transformation

This algorithm is a conventional geolocation method, and is referred to convert from image (line, pixel) coordinates to Cartesian (X, Y, Z) coordinates. It is possible to solve a set of below equations.

$$R = \left|\mathbf{R_s} - \mathbf{R_t}\right| \tag{1}$$

$$f_{Dc} = \frac{2}{lR}(\mathbf{V_s} - \mathbf{V_t}) \cdot (\mathbf{R_s} - \mathbf{R_t}) \tag{2}$$

$$\frac{x_t^2 + y_t^2}{(R_e + h)^2} + \frac{z_t^2}{R_p^2} = 1 \tag{3}$$

The accuracy of this geolocation algorithm depends on sensor position and velocity vectors, the measurement of the pulse delay time, and the knowledge of the target height relative to the assumed Earth ellipsoid model. Assuming that the information of the satellite position and the imaging time is accurate, the target height contributes to the geolocation errors. Since the target height is used DEM data assumed Earth ellipsoid model, the location of the target has some elevation errors.

2) Cartesian to Image Coordinates Transformation

If we reverse the referred geolocation steps, the mapping of the SAR image is more accurate. That is the conversion from Cartesian (X, Y, Z) coordinates to image (line, pixel) coordinates. It is possible to solve a set of equations below and to update the solution using the Newton method.

$$\begin{aligned}\frac{df_{Dc}}{dt} = \frac{2}{lR}\Big((\mathbf{R_s} - \mathbf{R_t}) \cdot (\mathbf{A_s} - \mathbf{A_t}) \cdot \left|\mathbf{V_s} - \mathbf{V_t}\right|^2 \\ - (((\mathbf{R_s} - \mathbf{R_t}) \cdot (\mathbf{V_s} - \mathbf{V_t}) / R)^2\Big)\end{aligned} \tag{1}$$

$$dt = \Delta f_{Dc} \Big/ \frac{df_{Dc}}{dt} \tag{2}$$

The accuracy of this reverse geolocation algorithm depends on not only sensor position- and velocity- vectors, and imaging pulse time, but also a DEM data over the illuminated area. As this algorithm is the part of the radar image simulation, it requires intensive computation. Since a DEM data is provided, we are able to have more accurate location of the target position and height. The radar simulated images, which is the by-product of the reverse geolocation algorithm, is available to geocode a SAR image, generate a differential interferogram, and create a synthetic image with another actual SAR image, etc.

4. Results

Table 1 shows the result of the conventional geolocation algorithm on the order of degree. The map coordinates are based on the geographic projection and the WGS84 datum. The symbol ' Ä' means the difference between the calculated results and the absolute geographic coordinates. The mean values of the planimetric distance error are –41.4m and 134.5m, and the standard deviations are 17.71m and 70.17m in the direction of latitude and longitude, respectively. The calculated target height error from the solution of a set of equations is not considered in this study.

Table 2 presents the estimation through the reverse geolocation algorithm processing. The averages of the error are –23.3m and 3.9m, and the standard deviations are 19.34m and 17.25m in each northing and easting direction, respectivley. The results clearly show the improvement of the new method compared with the conventional geolocation method. In addition, the elevation of the target from the DEM data has very small error.

To evaluate the effect of the DEM resolution, we also tested using a higher resolution DEM. The results show a fewer differences.

Table 1. The map coordinates of the selected tiepointing using the conventional geolocation algorithm.

No	Lat	Lon	Älat	Älon
1	36.364383	127.389021	-0.000309	0.001006
2	36.359433	127.380467	-0.000391	0.001100
3	36.337857	127.394467	-0.000426	0.001191
4	36.350527	127.413411	-0.000393	0.000780
5	36.342068	127.424433	-0.000422	0.000930
6	36.346761	127.433212	-0.000762	0.001202
7	36.366250	127.332430	-0.000567	0.001337
8	36.358313	127.330183	-0.000286	0.001450
9	36.322139	127.239662	-0.000554	0.003385
10	36.340331	127.374918	-0.000069	0.001239
11	36.357333	127.380549	-0.000372	0.001175

Table 2. The map coordinates of the selected tiepointing using the inverse geolocation algorithm.

No	Lat	Lon	Älat	Älon
1	36.364483	127.388126	-0.000209	0.000111
2	36.359567	127.379390	-0.000257	0.000023
3	36.338017	127.393398	-0.000266	0.000121
4	36.350667	127.412363	-0.000253	-0.000269
5	36.342217	127.423398	-0.000273	-0.000106
6	36.346917	127.432043	-0.000606	0.000033
7	36.366383	127.331335	-0.000434	0.000241
8	36.358450	127.329043	-0.000149	0.000310
9	36.322650	127.236293	-0.000043	0.000016
10	36.340550	127.373501	0.000150	-0.000178
11	36.357483	127.379501	-0.000222	0.000127

5. Conclusion & Discussion

We developed a reverse geolocation algorithm and applied to the Daejon area using the ESA ERS image and USGS GTOPO-30 DEM data. The results through the reverse geolocation method showed smaller errors than those from the conventional geolocation. Although the calculated location coordinates is not corrected with any data processing and system parameter compensations, the relatively small errors encourage us to apply the SAR data to mapping.

The geolocation is useful to many branches of geometric rectification, map correction, and other remote sensing applications. Especially, the geolocation using radar image is good for areas without known maps and distinguishing objects in images, i.e. oceanic scenes or cloud obscured interior land areas, and extraterrestrial surfaces.

There is room for improvement to our results in some aspects. The one is the system parameter about the pulse delay time or imaging time. The azimuth imaging time in the ancillary information provided with radar images has a little gap in comparison with real value. It is known from the correlation of the simulated image with the raw image. Therefore we can generate more accurate map coordinates in azimuth or latitude direction. The other is the quality of the DEM data. The inverse geolocation algorithm is dependent of the accuracy of the DEM data, because it uses the position of the illuminated target area apart from the conventional geolocation method.

An additional statistical analysis is required so that the statistics referred above is computed with all selected tie-points. In spite of the radar image with unique speckle noises, we will extract the tie-points from the entire image for the examination.

In addition to the Daejon area, we applied our algorithm to the Seoul area in Korea with GPS survey data instead of the digital maps. The generated geographic coordinates show the systematic error in longitude direction. Once we concluded that the results were caused by the satellite orbit error or the quality of DEM data in a big city. In the future works, we will investigate the effect of those parameters in that area.

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