SAR Processing Software for Ground Station

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Abstract: Satrec Initiative (Si) is developing a ground processing system for Synthetic Aperture Radar (SAR) data. SAR provides its own illumination and is not dependent on the light from sun, thus permitting continuous day/night operation and all-weather imaging. The system is capable of producing standard level products from SAR signal. Hence, the system should be able to perform matched filtering, range compression, azimuth compression, multi-look image generation, and geocoded image generation. This paper will describe the processing steps including algorithms, design, and accuracy of the Si’s SAR processing system by comparing with commercial software.

Keywords: SAR, Processing, Ground Station.

1. Introduction

As the use of optical sensor image is being increased, users’ needs for other types of sensor data such as SAR and hyper-spectral become bigger, because the image users want to acquire images more often, see other spectrum of the earth and so on. Our system has been developed to satisfy such requirements. The system consists of two subsystem including: Data Receiving and Archiving subsystem and SAR Processing subsystem. Data Receiving and Archiving subsystem receives the SAR signal from satellite and records the data to RAID, and the SAR Processing subsystem produces the image data from the archived SAR signal. In this paper, we examine the SAR Processing subsystem.

2. SAR Processing

The SAR processing involves parameter estimation and range-Doppler processing. The parameter estimation includes procedure for determination of Doppler parameters (the Doppler frequency and Doppler rate) and the range-Doppler processing is the most commonly used algorithm for processing continuously collected SAR data into an image [1][2]. The Fig. 1 shows the processing steps.

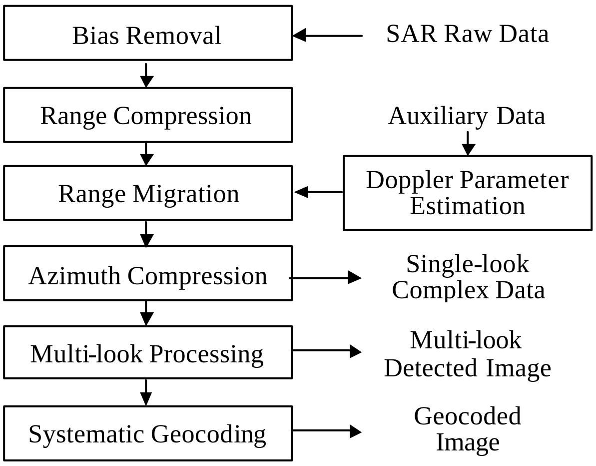


Fig. 1. Overview of the process.

1) Bias Removal

This is raw data correction step to remove the In phase and Quadrature bias. That is the setting of the correct 0 volt level for converting digitized and unsigned raw data back to original signal levels. We propose the 3 methods; Full Dynamic Range, Full Data and Line by Line, and each method can be applied to the various SAR images.

The Full Dynamic Range is the method on the assumption that the AD converter in the receiver of SAR satellite is very correct. Thus the 0 volt level uses the T/2 (the full level is 0~T). So, the bias of ERS1/2 is 15.5 and JERS 1’s is 3.5. The Full Data is method to set the bias by the average processing of I/Q data of received image. As shown in the Table 1, the ERS-2 is very similar to system bias 15.5, but JERS-1 is different. So, we can use the system bias for ERS, but only the bias calculated from real data for JERS-1. The Line by Line is a method averaging I/Q data line-by-line. The Table 2 shows the minimum and maximum of averaged I/Q data calculated by line-by-line. We can apply the Full Data and Line by Line method for JERS, but the Line by Line method depends on the target properties. In our system, we used the Full Dynamic Range for the default method of ERS and Full Data for JERS. However user can change the method from the configuration.

Table 1. The average of I/Q data in Full Data method

	I bias	Q bias
JERS-1 Seoul	3.342879	3.068395
ERS-2 Alaska	15.50656	15.45055
ERS-2 Seoul	15.49931	15.47531

Table 2. The minimum and maximum values of line-by-line average of I/Q data

	I min / max	Q min / max
JERS-1 Seoul	3.17 / 3.51	2.89 / 3.30
ERS-2 Alaska	15.24 / 15.72	15.18 / 15.68
ERS-2 Seoul	15.33 / 15.67	15.41 / 15.67

2) Range Compression

In collecting the SAR data, a long-duration linear FM pulse is transmitted. This allows the pulse energy to be transmitted with a lower peak power. The linear FM pulse has the property that the result becomes a narrow pulse in which all the pulse energy has been collected to the peak value. Thus, when a matched filter is applied to the received echo, it is as if a narrow pulse was transmitted, with its corresponding range resolution and signal-to-noise ratio.

This matched filtering of the received echo is called range compression. Range compression is performed on each range line of SAR data and can be done efficiently by the use of the Fast Fourier Transform (FFT). The frequency domain range matched filter needs to be generated only once, and it is applied to each range line, as shown in Fig. 2. The matched filter can be generated from a replica of the transmitted pulse.

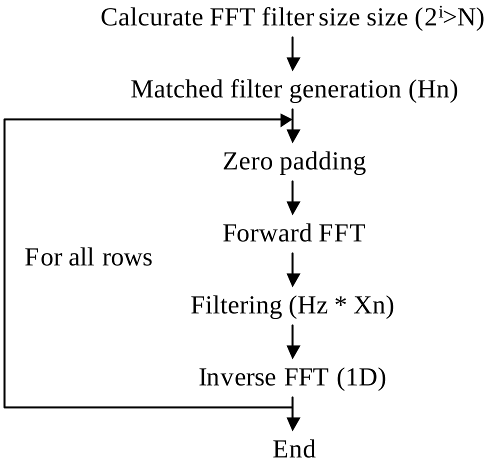


Fig. 2. The range compression process.

3) Range Migration Correction

The azimuth processing performs on the assumption that the data in the same range bin has the same Doppler parameter. But the real data does not, because of range skew and range curvature. The correction of range bin misalignment is range migration correction.

The range migration correction consists of two steps. The first step, bulk range walk correction applies the same shift factor to whole image while the range compression, and the next step performs remaining small range walk and full range curvature correction at frequency domain in azimuth compression.

The important process for follow steps is the Doppler parameter estimation. The Doppler centroid estimation error would result in the loss of signal-to-noise ratio and ambiguity, and Doppler rate estimation error would lead to significant defocusing (blurring) of the image.

The Doppler parameter estimation uses the ancillary data (position, velocity and attitude information) of satellite. Using these ancillary data, the SAR camera model calculates the coordinates on earth surface corresponding to the pixel/line coordinates of an image, and then we calculate the Doppler Parameter, that is the relative speed and acceleration of the platform to the earth surface [3][4].

Such procedures are inherently quite accurate, up to the level of accuracy of the attitude measurement instrumentation and the accuracy of the satellite orbital parameters computed from tracking data. It can be, however, that instrumentation difficulties limit the former, while the time lag in smoothing and refining tracking data may make it inconvenient to use the latter. For these reasons, we include procedures for automatic determination of the Doppler parameters that are called clutterlock and autofocus algorithm [5][6][7].

4) Azimuth Compression / Multi-look processing

Azimuth processing is a matched filtering of the azimuth signal, performed efficiently using FFT's. The processing step is similar to Fig.2 of range compression, but the different point is that we calculate the transfer function for every range bin, because the Doppler centroid and Doppler rate are changed along the range bins.

The extracted frequency array for each look is multiplied by the matched filter frequency response and the inverse FFT is performed to form the complex look image. The matched filter frequency response is adjusted by a small linear phase ramp for each look. This is equivalent to shifting the compressed look in time and is required to ensure that the images from different looks are aligned properly for look summation. The amount of azimuth shift is range dependent. In addition, azimuth interpolation can also be performed after look compression to achieve a desired azimuth pixel spacing, and it is done on each look separately. After look compression, each of the look images is detected. That is, the power of each complex sample is calculated. The detected azimuth looks are then summed, and the square root of the result is calculated to convert to magnitude. Multi-look is a popular technique to reduce the speckle effect. The Fig. 3 shows the resultant multi-look image.

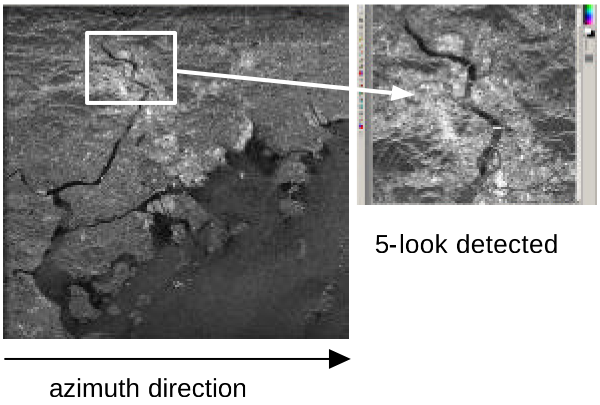


Fig. 3. The multi-look image.

5) Systematic Geocoding

SAR data geocoding is a very important step for many users because SAR data should be corrected geometrically in order to be compared or integrated with other types of geographic data (satellite images, maps, etc.).

Geocoding an image consists of introducing spatial shifts on the original image in order to have a correspondence between the position of points on the final image and their location in a given map projection. And it is the process of resampling the data to conform to a standard map projection with known co-ordinates. The processing steps are calculation of scene boundary and linear buffer using Forward mapping, filling the content of linear buffer using the Inverse mapping, and then determination of all pixel values using the resampling. The Fig. 4 shows the SAR Inverse camera model procedure.

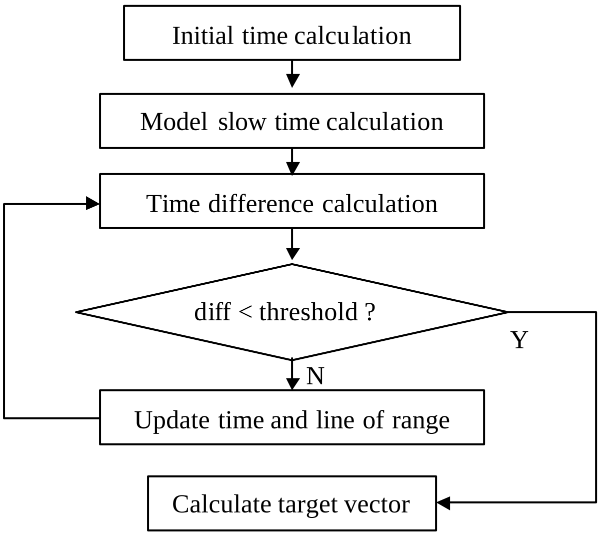


Fig. 4. SAR Inverse camera model.

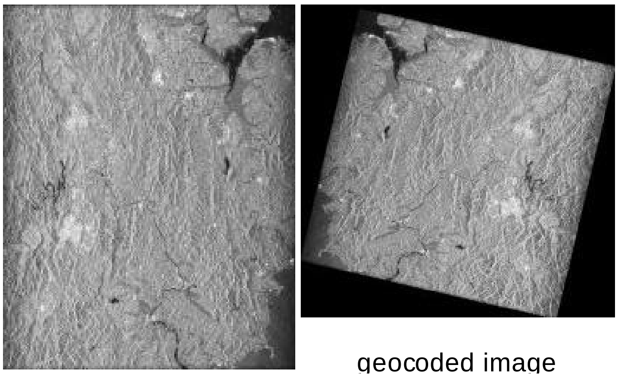
Table 3 shows the difference of commercial software and our result in geometric point. This experiment uses ERS-2 images. In case of ERS-2 image, it has no attitude information (pitch, roll, yaw), so the relative difference does not mention which algorithm is better than others. The Fig. 5 shows our systematic geocoded result [8].

Table 3. The difference of commercial software and our system.

	RMS_X	RMS_Y	RMS
Seoul	84.845 m	355.403 m	365.390 m
Daejeon	45.135 m	193.678 m	198.868 m

3. Conclusions

The result shown in this paper is intermediate, because the development of the currently introduced system is going on. We focused on implementing the whole steps for getting SAR image product. In coming years, we will improve quality and accuracy, and then the developed system can be used for ground process system for SAR satellite.



geocoded image

multi-look image

Fig. 5. The systematic geocoded image of Daejeon, Korea.

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