International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Mitigation of Azimuth Ambiguities in SAR Images Using Restoration Techniques

Aashna Hassan

PG Student, Department of Electronics and Communication, Mount Zion College of Engineering,
Kadammanitta, Pathanamthitta District, Kerala, India

Abstract: ***A framework is proposed for mitigating azimuth ambiguities in spacebornestripmap synthetic aperture radar (SAR) images. The azimuth ambiguities in SAR images are localized by using a local mean SAR image, SAR system parameters and a defined metric derived from azimuth antenna pattern. The defined metric helps isolate targets lying at locations of ambiguities. The mechanism for restoration of ambiguity region is selected on the basis of size of ambiguity regions. A compressive imaging technique is employed to restore isolated ambiguity regions (smaller regions of interconnected pixels), whereas clustered regions (relatively bigger regions of interconnected pixels) are filled by using exemplar-based inpainting. The simulation results on a real TerraSAR-X data set demonstrated that the proposed scheme can effectively remove azimuth ambiguities and enhance SAR image quality.***

Keywords: Image processing, Image restoration, Synthetic Aperture Radar (SAR).

1. Introduction

SPACEBORNE synthetic aperture radar (SAR) systems have attracted special interest in remote sensing tasks such as surveillance, target and object detection, land classifications, disaster search and rescue, and homeland security. Recently, high-resolution SAR imagery has been employed for cyclone intensity estimation, ship classification, moving target detection, oil field monitoring, 3-D building reconstruction, and feature detection. The advanced and sophisticated applications also require high-quality SAR imagery free of artifacts. However, the spaceborne SAR imagery exhibits ambiguities which may lead to faulty interpretation of SAR imagery. The ambiguities are mainly divided into two categories, i.e., range ambiguities and azimuth ambiguities. Range ambiguities are shown as highly deformed images, resulting from mismatched Doppler rate. Azimuth ambiguities are high-frequency spectral contributions, down converted by sampling having similar Doppler rate with respect to the ground targets illuminated by the antenna main lobe.

Finite sampling of azimuth Doppler signals introduces azimuth ambiguities in spaceborne SAR images. Aliased signals are produced due to folding of Doppler frequencies toward the central part of antenna pattern in Doppler frequency domain. The ambiguous signals will be displaced symmetrically in azimuth toward the right and left of the actual target position. Azimuth ambiguities cause decreased signal-to-noise ratio (SNR) and lead to unreliable visual quality of the SAR image.

The postprocessing techniques to address azimuth ambiguities can be divided into two categories, i.e., based on bandpass filtering and in-phase cancellation. Bandpass filtering technique removes azimuth ambiguities by using bandpass filters (BPFs) to filter azimuth signals. The bandpass filtering technique is effective in suppressing azimuth ambiguities but results in lower SNR, decreased effective Doppler bandwidth, and additional speckle noise. Guarnieri [1] introduced an adaptive approach for filtering process to help lessen induced speckle noise at locations where ambiguous signals are small by employing an adaptive Wiener filter. The performance of the Wiener filter is very sensitive to SNR.

The second type of azimuth ambiguity mitigation techniques is called in-phase cancellation techniques [3], [4]. These techniques design a reference function that provides matched filtering of the desired signal and deconvolves the ambiguities. The in-phase cancellation techniques are effective for SAR images having strong point targets but subject to poor performance for distributed targets, because high-frequency components of reflectivity spectra are unrecoverable.

2. Azimuth Ambiguities

In Figure 1, the desired target illuminated by the antenna main lobe is referred to as O, and two ambiguous targets which are illuminated by the antenna sidelobes are denoted as GR and GL. The contributions coming from targets GR and GL are displaced in azimuth by angles ΔϕR and ΔϕL, respectively. The signals from the main main target and ambiguous targets are added coherently according to AAP. The contribution from the ambiguous targets becomes indistinguishable. At each azimuth position, an infinite number of such ambiguous signals are received simultaneously.

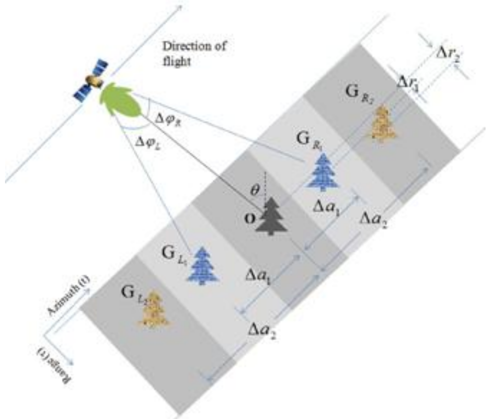

Figure 1: SAR Geometry for azimuth ambiguities

3. Proposed Ambiguity Removal Framework

The proposed ambiguity removal framework is shown in Figure 2. The SLC data of SAR are processed to find out locations of pixels which are dominated with ambiguous contributions. Classify azimuth ambiguities into two categories, namely, clustered ambiguities and isolated ambiguities. If ambiguity regions appear in the form of connected pixels of size greater than 50 pixels, as clustered ambiguities, with all other ambiguity regions termed as isolated ambiguities. The pixels in ambiguity regions in SLC data are assumed to be unknown, and selective restoration mechanism is used to find the values of these pixels. The pixels in isolated ambiguity regions are found out by employing a recently developed compressive imaging framework, whereas the pixels in clustered ambiguities are restored by using exemplar-based inpainting technique.

Selective restoration strategy is adopted to achieve better restoration with computational efficiency. Compressive restoration is efficient but may result in poor restoration for clustered ambiguities. Therefore, exemplar-based inpainting, which is computationally inefficient, is employed to restore clustered ambiguities only.

A. Localization of Ambiguities

Each target in a space borne SAR image imparts its ghosts at azimuth frequencies that are integer multiples of PRF. A target O would impart I number of significant ambiguity image pairs on both the right and left sides. For localization of ambiguity regions in a stripmap SAR image, a local mean SAR is employed along with approximated azimuth and range shifts of ambiguities. A local mean SAR image is obtained by convolving an SCL SAR image with an averaging kernel.

The local mean SAR image helps take into account the SAR parameter estimation error and defocusing phenomenon of distributed images. Moreover, many structures in populated areas behave as distributed/complex targets with several scattering centers. A distributed/complex target and its corresponding ambiguity image share similar structure but may differ in many details, as shown in Figure 3. It can be observed that the ambiguity image is blurred in azimuth direction and has details that are also different compared to those of the actual target.

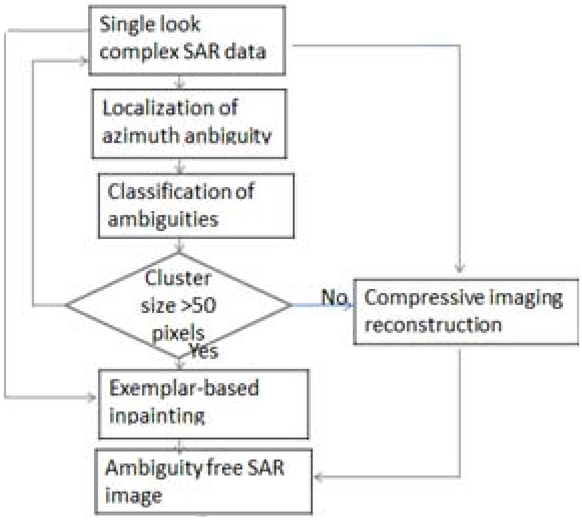

Figure 2: System architecture

B. Mitigation of Ambiguities

The isolated ambiguities are restored by applying a compressive imaging framework, whereas clustered ambiguities are found out by exemplar-based inpainting technique. In order to increase computational efficiency of filling clustered ambiguities, the SAR image can be divided into segments based on texturedness. The SAR image is quite uniform in the areas of forest and sea, whereas populated areas appear as textures.

4. Experimental Results

The proposed azimuth ambiguity mitigation framework was tested on a TerraSAR-X data set. The TerraSAR-X image of Dubai coastal area (Jebel Ali port) with strong azimuth ambiguities is shown in Figure 4.The ambiguities of a concrete/metallic rectangular structure can be seen on both the left and right sides in azimuth directions. The left ambiguity appears on uniform background, i.e., sea, whereas the right ambiguity appears on populated areas.

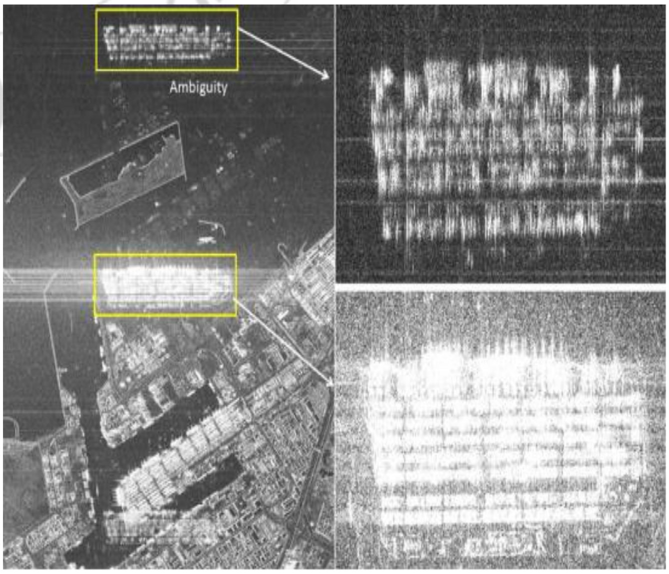

Figure 3: Structure of ambiguities. (Left) TerraSAR-X image patch with distributed target and its ambiguities. (Right) Rescaled target and its ambiguous images

If a very weak target is fully corrupted by strong ambiguous signals, the whole target may be marked as an ambiguity region, and we may lose the target. However, if a very weak target is partially marked as ambiguity due to strong ambiguities, still, it can be reconstructed by using the framework. Three important features of the proposed ambiguity mitigation framework can be observed.

1) The filtering technique decreases SNR, whereas the proposed technique does not deteriorate signal quality.
2) The strong and distributed ambiguities are not removed completely using the BPF technique, as can be observed in Figure 4, but the proposed framework can remove these ambiguities satisfactorily.
3) The bandpass filtering technique results in blurring of the SAR image, whereas the proposed framework would not lose spatial resolution of the SAR image.

5. Discussion

The increased interest of research community in linear inverse problems would lead to highly efficient restoration algorithms in near future. Inverse problem relates to signal and image restoration process. Exploiting latest research in these areas, the proposed framework would be a pragmatic and computationally efficient option for mitigation of azimuth ambiguities in spacebornestripmap images.

The proposed framework will be extended for ambiguity mitigation in spaceborne high-resolution spotlight/slidingspotlight SAR images in the future. The azimuth ambiguity in spotlight/sliding-spotlight SAR exhibits different behaviour compared to spacebornestripmode SARs. Therefore, AASR in spotlight/sliding-spotlight SAR images varies as a function of azimuth position, and new formulation for localization of ambiguities would be required to deduce.

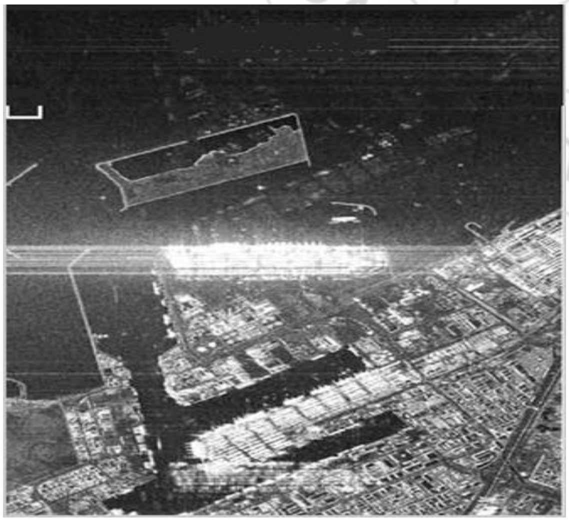

Figure 4: Removal of azimuth ambiguities using proposed framework

6. Conclusion

A framework based on selective restoration has been proposed for removal of azimuth ambiguities in spacebornestripmap SAR images. The azimuth ambiguities in stripmap images are identified through a simple and effective technique by employing a metric derived from AAP. The ambiguous locations are predicted by selecting either compressive imaging or exemplar-based inpainting technique based on size of the ambiguous region. The experimental results on real SAR data have demonstrated that the proposed ambiguity mitigation framework is better compared to filtering-based reduction techniques.

The proposed framework will be extended for ambiguity mitigation in spaceborne high-resolution spotlight/sliding spotlight SAR images in the future. The azimuth ambiguity in spotlight/sliding-spotlight SAR exhibits different behaviour compared to spacebornestripmode SARs. Therefore, AASR in spotlight/sliding-spotlight SAR images varies as a function of azimuth position, and new formulation for localization of ambiguities would be required to deduce accordingly.

7. Acknowledgments

This field has seen tremendous developments over the last two decades, and it is not possible to include all relevant references to all the subjects that are discussed. To give a coherent coverage to such a broad field, the authors have discussed and referenced work they are most familiar with in greater detail. The author acknowledges and apologizes for the many omissions that necessarily have resulted.

References

[1] A. Criminisi, P. Perez, and K. Toyama, “Region filling and object removal by exemplar-based image inpainting,” IEEE Trans. Image Process., vol. 13, no. 9, pp. 1200–1212, Sep. 2004
[2] A. Guarnieri, “Adaptive removal of azimuth ambiguities in SAR images,” IEEE Trans. Geosci. Remote Sens., vol. 43, no. 3, pp. 625–633, Mar. 2005.
[3] A. Moreira, “Suppressing the azimuth ambiguities in synthetic aperture radar images,” IEEE Trans. Geosci. Remote Sens., vol. 31, no. 4, pp. 885– 895, Jul. 1993.
[4] D. Donoho, “Compressed sensing,” IEEE Trans. Inf. Theory, vol. 52, no. 4, pp. 1289–1306, Apr. 2006.
[5] J. Chen, J. Gao, Y. Zhu,W.Wang, and P.Wang, “A novel image formation algorithm for high-resolution wide-swath spaceborne SAR using compressed sensing on azimuth displacement phase center antenna,” Progress Electromagn. Res., vol. 125, pp. 527–543, 2012.
[6] P. Sen and S. Darabi, “Compressive rendering: A rendering application of compressed sensing,” IEEE Trans. Vis. Comput. Graphics, vol. 17, no. 4, pp. 487–499, Apr. 2011.
[7] Z. Zhang and Z.-S.Wang, “On suppressing azimuth ambiguities of synthetic aperture radar by three filters,” in Proc. CIE Int. Conf. Radar, 2001, pp. 624–626.