CHIRP SCALING BASED DETECTION OF MOVING TARGETS IN SAR IMAGES

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1. INTRODUCTION

As it is well known, moving targets within SAR images appear shifted and/or smeared due to their motion [1]. In particular, the target velocity component in the cross-track direction results in an erroneous azimuth localization of the mover due to the intrinsic SAR ambiguity between azimuth angle and Doppler frequency. On the other hand, an along-track target velocity component detemines a variation in the resulting azimuth chirp rate and a consequent mis-match with the parameters used to focus the stationary scene, thus giving rise to target smearing. When dealing with moving target detection within single-channel SAR images, the former effect does not highly affect the detection capability, since only a displacement in the target positioning is experienced. In contrast, the latter effect might deeply deteriorate the target detection probability. This because the erroneous matching between the azimuth signal received from the target and the reference azimuth chirp used in the focusing algorithm determines a reduction in the achievable Signal to Clutter plus Noise Ratio (SCNR). A viable solution to recover the detection capability is to design a more complex focusing algorithm which takes into account a possible along-track movement of the target, thus synthesizing several azimuth compression filters each one matched to a different relative along-track velocity between SAR sensor and moving target, as described in [2]. Given an interval of interest for the target along-track velocities, the number of focusing filters in the bank can be derived analitically, [2]. A high number of filters directly determines an increase in the computational cost. To limit this effect, we propose to implement the bank of focusing filters using a computational efficient focusing algorithm, like the Chirp Scaling Algorithm (CSA) [3]. The increased moving target detection capability due to the bank of filters is shown using as a case study a SAREX-92 image of the Tapajos rain forest with super-imposed synthetic returns from several moving targets. The performance of the proposed scheme is evaluated in terms of target detection probability versus SCNR, for several target velocities. Moreover, in order to relocalize the detected movers, the availability of a second channel is also considered to estimate the target along-track displacement by using Along-Track-Interferometry (ATI) techniques. The performance of the proposed relocalization technique is investigated in terms of provided accuracy.

2. CSA BASED MOVING TARGET DETECTION TECHNIQUE

The technique proposed in this paper to detect moving targets in SAR images is based on a bank of L Chirp Scaling focusing Algorithms, each one matched to a different possible target velocity component in the along-track direction. This means that in each filter within the bank, the along-track sensor velocity V_a has to be replaced with the relative along-track velocity between sensor and target ($V^{(i)}$). Consequently, all the processing steps which depends on V_a have to be parallelized and customized, leading to the processing scheme sketched in Figure 1 (Φ_1, Φ_2, and Φ_3 are the phase multiplication terms of CSA). The number of parallel branches L is easily determined by fixing a reasonable interval of target velocities and by knowing the overall synthetic aperture time. Each mover produces an output image in each filter, with a maximum peak level in the filter that better approximates the relative along-track velocity between target and sensor. A proper threshold (as for example obtained via a Cell Average CFAR) can then be applied to each output image to detect the movers. It is worth to notice that, in the CSA, the RCM (Range Cell Migration) equalization and correction depends, analytically, on the platform velocity V_a and, therefore, has been parallelized in the considered bank of CSA. However, at least in first approximation, the along-track target motion causes only a mis-match in the azimuth signal. Consequently, a bank of filters with a reduced computational burden can be derived parallelizing only the azimuth compression steps (multiplication with Φ_3 and final azimuth IFFT). A performance analysis of such a scheme will be presented in the final paper. A second remark deals with the considered target velocities and the available slant range resolution. Especially for targets with high radial motion, the cross-track velocity component causes a target cell migration during the synthetic aperture. This results in a smearing of target signal energy over several range cells, thus reducing the signal peak level and the detection probability. To overcome this problem, it is possible to deteriorate the slant range resolution so that no cell migration due to radial target motion is experienced, leading to a target detection in a low-resolution image, or more in general to follow recursive procedures. A comparison between the performance provided by the “full-resolution” and the “low-resolution” detection approach will be presented in the final paper.

3. MOVING TARGET DETECTION AND PERFORMANCE EVALUATION

The performance of the proposed technique is investigated by using a SAREX-92 image of the Tapajos rain forest. The available SAREX image is focused in the slant range-azimuth plane with a resolution of 6 meters and a pixel spacing of 4.5 meters. To use such an input image for our purposes, an inverse focus processing has been applied to obtain the raw SAR data of stationary background. To do this, a flat Earth geometry has been supposed with the SAR working in non-squinted stripmap mode. This raw image has been added to synthetic raw returns from several targets moving along roads A and B. Figure 2 reports the resulting focused image applying the traditional CSA, hence a focusing matched to the stationary scene. Moving targets inserted in the image are represented by colored dots in their true position, an arrow indicating the corresponding motion. Circles of the same color indicate their smeared and displaced echo in the focused image. Targets velocities and relative components in the cross/along-track directions, are reported in Table 1. The maximum target velocity of 22 m/s has been selected considering the particular environment. For our study case we get a resulting number of filters $L=11$, [2]. As apparent, defocusing due to along-track target motion causes a reduction in the target peak signal (i.e. a reduction in the SCNR), hence making more difficult the target detection. In the final paper, the detection probability (P_d) versus target RCS for the considered movers when the bank of filters is used will be compared to the detection probability achievable by applying the traditional CSA processing. An additional target re-location procedure can be considered by synthesizing a dual-channel raw SAR dataset starting from the available SAREX-92 image. An estimation of the target along-track displacement, hence of the radial velocity component, can be performed recalling to ATI techniques.

Target	Velocity [m/s]	Cross-track component [m/s]	Along-track component [m/s]
1A (red)	22	5.37	21.28
2A (green)	10	2.44	9.67
3A (dark blue)	5	1.22	4.83
1B (purple)	-10	-8.78	-4.13
2B (yellow)	-22	-19.33	-9.10
3B (brown)	18	15.83	7.44
4B (light blue)	7	6.16	2.89

Table 1 – Considered target velocities

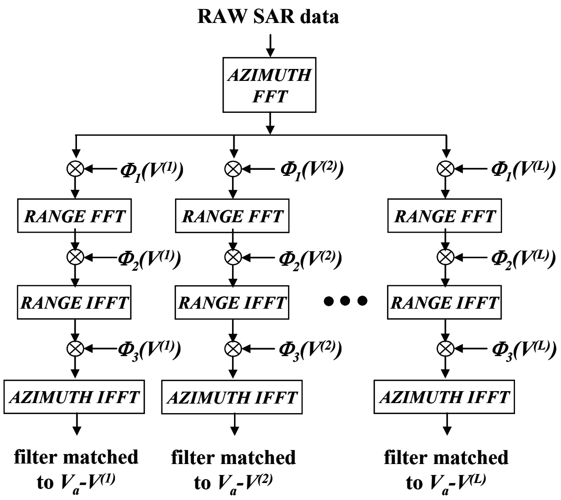

Figure 1 – Bank of CSA filters

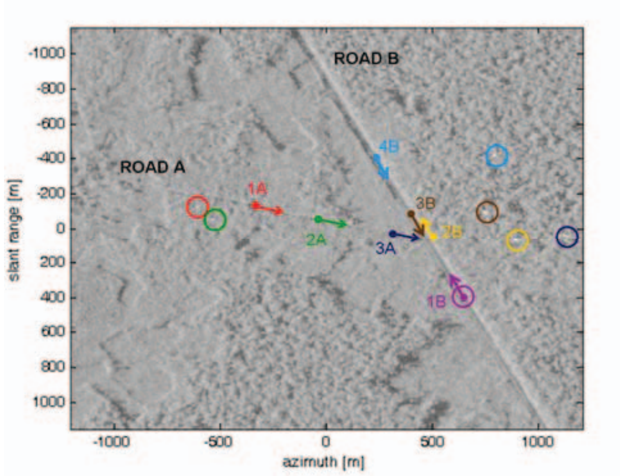

Figure 2 – SAREX image with synthetic movers

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