SAR TOMOGRAPHY FROM SPARSE SAMPLES

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A single-channel Synthetic Aperture Radar (SAR) sensor produces a high resolution two-dimensional (2-D) image of the observed scene [1], representing a projection of the 3-D scene scattering properties onto the 2-D azimuth-range plane, while it's not able to obtain the reconstruction of the scene backscattering properties along the elevation direction, which is normal to the azimuth-range plane.

Interferometric Synthetic Aperture Radar Systems (InSAR) exploit two antennas looking at the scene with two slightly different view angles (single-baseline InSAR), and allow the estimation of the 3-D altimetric profile of the imaged scene, as the ground height profile is related to the SAR interferometric phase through a know mapping [2]. However, single-baseline interferometric techniques do not allow obtaining the scatterers distribution along the height direction.

With the use of Polarimetric SAR interferometry it is possible the discrimination of different scattering mechanisms within the azimuth-range SAR resolution cell [3], but it is not possible to separate the contributions of the same scattering mechanism distributed over different heights.

Multi-baseline (or multi-pass) SAR techniques, often referred as SAR tomography, instead, allow generating 3-D images, which for each azimuth and range position provide an estimation of the scatterers distribution along the elevation direction [4-6].

SAR tomography introduce new possibilities for many applications, such as archaeology or geology, and then has received great interest in recent years. It essentially consists in the formation of a second synthetic aperture along the elevation direction, in addition to the synthetic aperture along the azimuth direction [5]. The aperture synthesis in the elevation direction can be performed by using several multi-pass acquisitions on the same scene, taken with different view angles. At this purpose, two problems have to be taken into account: the number of acquisitions in the elevation direction is usually much lower than the number of acquisitions along the azimuth direction, and the samples in elevation are unevenly spaced, due to the non-uniform spatial separation among the different passes. Moreover, numerical efficiency is highly desirable since the aperture synthesis in the elevation direction has to be performed for each image pixel in the azimuth-range plane.

The above mentioned problems can introduce a degree of ill conditioning in the processing step required for focusing in the elevation direction, that may generate severe ambiguities and numerical instabilities in the elevation imaging process [5,6]. To regularize the problem, a time consuming inversion techniques based on Singular Value Decomposition (SVD) has been applied in [6]. In [7] the application of the non-uniform sampling theorem has been proposed, to recover the uniform signal samples in the elevation direction starting from the knowledge of non uniform samples. The theorem applied exploits the band-limited properties of the signal acquired along the elevation direction, and imposes a constraint on the maximum sampling interval and on the samples average densuty.

In this paper we investigate the possibility of applying a method which reduces the informative measurements, still allowing to obtain the 3D image, based on Compressive Sampling (CS) [8,9].

CS is a model-based framework for data acquisition and signal recovery based on the premise that a signal having a sparse representation in one basis, Ψ, can be reconstructed from a small number of measurements collected in a second basis, Φ, that is incoherent. Sparsity refers to signals that have concise representations when expressed in a proper basis Ψ, f.i. in our case sparseness requires a small number of point-like targets. Incoherence expresses the idea that objects having a sparse representation in Ψ must be spread out in the domain in which they are acquired (Φ). Instead of measuring conventional returns and sampling it at the Nyquist rate, linear projections of the returned signal with random vectors are taken as measurements.
Then, by l_1-norm minimization it is possible to reconstruct the full-length signal from the small amount of collected data. CS specifies a protocol that can be exploited in SAR tomography to acquire samples along unevenly spaced orbits, in a signal independent fashion, at a low rate and later uses computational power for reconstruction from what appears to be an incomplete set of measurement.
Numerical results will be presented on simulated data and the method performances will be discussed in terms of resolution that can be achieved with a given acquisition configuration.

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