A Comparative Study of L1-minimization, Total Variation Minimization, and Group Sparse Reconstruction in Imaging of GPR Targets under Noise

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In recent years, compressive sensing (CS) has been successfully applied in a large class of radar imaging problems for both defense and civilian applications. CS is particularly well-suited for radar applications, such as those in ground penetrating radar (GPR) and through-the-wall radar imaging (TWRI), which require development of fast data acquisition schemes with significantly reduced number of antennas and/or collected frequency points such that the detection and imaging of targets can be done in near real-time. Most variations of CS applied in layered subsurface imaging like in GPR, use standard L1-norm minimization. Standard L1 minimization is primarily effective in detecting the presence of targets, since it cannot accurately reconstruct shape of the extended targets and/or differentiate between closely-spaced targets and extended targets. Recently, an alternative sparse reconstruction technique based on total variation minimization (TVM) was proposed for subsurface and TWRI imaging, which was shown to provide better performance than standard L1-norm minimization in various layered media scenarios [W. Zhang and A. Hoorfar, 2017 SPIE CS VI Conference, Anaheim, CA]. In general, in TVM the gradient of an image is minimized which reconstructs the edges and shape of the objects better than conventional L1-minimization and also is more robust in the presence of noise.

An alternative sparse radar-image reconstruction technique is group sparse reconstruction (GSR), which has been employed in the past to account for extended targets [M. Leigsnering et al., IEEE Transactions on Aerospace and Electronic Systems, 50(2), pp. 920-939, 2014]. In this work, we perform a comparative study of TVM, GSR, and standard L1 minimization in step-frequency multi-input multi-output (MIMO) radar imaging of extended and crowded target scenes. In particular, we compare the efficiency and performance of these techniques for various subsurface and GPR scenarios both in the absence and presence of various noise levels. Incorporation of the layered media Green's function in the MIMO beamforming algorithm to accurately account for the wave propagation in subsurface layers, together with its efficient computation, will also be discussed in the presentation.