Advances in Sparse Image Reconstruction of GPR Subsurface Targets

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Over the years, the detection and imaging of targets embedded in layered media has become of paramount importance in a diverse set of problems including those in microwave remote sensing, nondestructive testing, ground penetrating radar (GPR), and through-the-wall imaging (TWRI). Specifically, development of imaging techniques for visually inaccessible targets buried under the ground has attracted growing interest in archaeology, underground weapon detection, building safety and durability assessment, geophysical exploration, etc. For high resolution imaging in these applications, usually a long aperture is synthesized using an ultra-wideband transmitted signal; this makes the approach impractical and/or costly in many realistic situations. To reduce the collected data volume in order to accelerate radar data acquisition and processing times such that prompt actionable intelligence would be possible, several research groups in recent years have applied Compressive Sensing (CS) to radar imaging in GPR to reconstruct a sparse target scene from far fewer non-adaptive measurements. The standard CS techniques, however, are mainly based on $L_1$-norm minimization, which is primarily effective in detecting the presence of targets as it cannot accurately reconstruct the target shape and/or differentiate closely spaced targets from an extended target.

In this presentation, we give an overview of our group's recent works on image reconstruction for both SAR-based and multiple-input multiple-output (MIMO) based GPR targets in a multilayered subsurface medium using CS. In our approach, the subsurface layers are accurately and efficiently accounted for in the sparse-image reconstruction through analytically derived expressions for the Green's functions of multi-layered lossy dielectric media. In particular, we will discuss the use of total variation minimization (TVM) and its advantages over the $L_1$-norm minimization which is often used in the standard radar implementation of CS. The TVM technique minimizes the gradient of the image instead of the image itself, and as a result leads to better shape reconstruction of large and/or multiple subsurface targets. In addition, we also discuss the use of group sparsity reconstruction (GPS) technique and compare its performance with that of TVM under various noise levels. Numerical results for sparse imaging in various subsurface scenarios using different reduced sets of SAR and MIMO radar transmit and receive antenna elements as well as reduced number of frequency bins will be given in the presentation.

How to cite: Hoorfar, A.: Advances in Sparse Image Reconstruction of GPR Subsurface Targets,