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Radar imaging

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FOREWORD

Radar imaging

Because of their ability to operate without regard to day, night or weather conditions, radar systems are ubiquitous in remote sensing operations and are used in a wide variety of commercial and military applications. High resolution radar *imaging*, however, is a remote sensing subcategory that requires raw radar data to be collected over an artificially extended aperture that is much larger than the radar receiving antenna and *processed* to create a reflectivity image of a scene (typically by backprojection methods). These synthetic aperture radar imaging (SAR) methods have been in use for over 50 years and, while the methodology for simple radar imaging is quite mature, there are still many active research programs seeking to extend the quality of—and information obtained from—SAR images.

At its heart, basic SAR imaging relies on a simplified model in which the electromagnetic waves propagate through vacuum from a known antenna location, and elements of the scene to be imaged are weakly scattering point-like elements whose relative positions are fixed during the data collection interval. When this model fails to accurately represent a particular imaging scenario, the usual result is image artifacts which confound follow-on interpretation. In the case of dynamic scenes, for example, we typically find that the locations of moving scene elements are often significantly displaced in the final image (relative to other scene components). This problem has been recognized for many decades but only recently have concerted research efforts been mounted to attack the issue.

Limitations associated with the point scatterer model are not quite so apparent as in the moving target case. Here, the problem is more one of lost information than artifacts (though associated image artifacts are possible as well). Generally, the echo response from a target will be characterized by more than just its intensity and more careful models have lately included depolarization effects and frequency dependence in an effort to more completely characterize the behavior of the reconstructed SAR image.

As with any computed image method there will, of course, be issues of effective and efficient algorithm design. Owing to the practical problems of collecting the radar data over a synthetic aperture (often measured by aircraft negotiating imprecise flight paths), the problem of SAR image reconstruction can be especially troublesome. Data registration errors, nonuniform sampling issues and wave propagation through complex media can adversely affect the reliability of the data by adding unknown phase errors which, in turn, reduce image resolution.

In this special section, we have invited contributions from many of the leading researchers in the mathematics, physics and engineering of SAR imaging techniques. The papers collected here fall (roughly) into three categories.

Target structure and composition. The papers by Albanese and Medina [1] and by Cheney [2] attempt to obtain the frequency dependence of scattering from a target or local areas of a scene. This could potentially add a dimension of 'color' to radar images. The paper by Voccola *et al* [3] develops a method for using a polarimetric SAR system to distinguish one-dimensional scatterers, such as fences and power lines, from other objects in the scene.

Artifact mitigation. The paper by the Bleszynski *et al* [4] addresses the mitigation of artifacts due to imprecise knowledge of the antenna trajectory. The key is to use the radar data itself to improve upon the coarser position estimates obtained from the Global Positioning System.

Two papers address the issues of SAR imaging with waves that propagate through a complex medium such as the ionosphere. The paper by Gilman *et al* [5] considers models specific to ionospheric wave propagation. These authors develop an artifact-mitigation method based on image registration from images formed from data collected at two distinct carrier frequencies. The paper by Garnier and Sølna [6] focuses on the attributes of randomness and dispersivity of the atmosphere or ionosphere, and identify their effects on SAR images.

The paper by Ferrara *et al* [7], on the other hand, assumes accurate knowledge of the antenna positions and propagation environment, and addresses the problem of combining data from multiple transmitters and receivers that may be sparsely and irregularly positioned. The case in which it is the targets that are sparse and irregularly positioned is addressed in the paper by Fannjiang and Tseng [8], who apply compressive sensing techniques to SAR image formation.

Moving targets. The following four papers all consider scenes that contain both moving and stationary objects. Jao and Yegulalp [9] develop methods for forming images from data collected from a moving antenna array. Marechal *et al* [10] analyze SAR data from targets with nonzero velocity and acceleration, and in particular they show that multiple combinations of velocity and acceleration can result in the same data. The paper by Borcea *et al* [11] develops two methods for estimating the motion of moving targets from data from a single moving antenna. The paper by Miranda and Cheney [12] develops methods for image formation from data collected by multiple fixed sensors in an environment that includes known multipath wave propagation.

We hope that this collection of papers will stimulate further research.

Brett Borden and Margaret Cheney

References

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