Interferometric SAR processing for jointly reconstructing target shape and three-dimensional motion in forward-looking geometries

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Forward-looking synthetic aperture radar (SAR) target imaging involves imaging a conducting structure that lies either on or very near the radar velocity vector. Geometrical data extracted from the resulting imagery can be used to estimate the target shape, orientation, and location relative to the radar. The geometric data may be two-dimensional if extracted directly from the focused imagery or three-dimensional if extracted via interferometric processing of images from multiple coherent receivers. In forward-looking (i.e., extreme high-squint) geometries, this data can be used for various applications related to situational awareness, such as collision avoidance or forward-looking reconnaissance.

Three-dimensional target motion data is also of interest for forward-looking situational awareness applications. In previous work, we have presented an interferometric SAR technique for jointly estimating both the target three-dimensional shape and three-dimensional velocity vector based solely on the radar data used to form the focused SAR imagery. The proposed approach is to apply a multiple-parameter convex optimization technique to the interferometric phase measured for each focused scattering center in the SAR image. The optimization is made well-conditioned by making multiple interferometric measurements for each scatterer using an overlapping-subaperture approach. A benefit to using this technique is that the interferometric technique is applied to high-resolution focused SAR imagery, which minimizes the risk of interfering scattering centers causing corrupted position and motion estimates.

In this presentation, we introduce an enhanced version of this technique which allows for estimation of more complex target trajectories. The technique is modified to estimate not only each scatterer's three-dimensional location and velocity, but also its three-dimensional acceleration. This enhancement requires the use of a larger number of overlapping subapertures in order to estimate a larger number of unknown motion parameters. The enhancement provides the radar platform with a more complete context for the possible hazards near its planned motion vector so that, for instance, optimal collision avoidance decisions can be made when necessary. In addition, incorporating more motion parameters into the inverse problem decreases the degree of model-error-based corruption in the resulting estimates.

In this presentation, we first describe the updated mathematical formulation of the proposed technique. We then generate simulated data for a variety of imaging scenarios with accelerating targets. We apply the simulated data to the technique and compare the resulting estimated parameters to truth. We quantify the resulting errors and characterize the sensitivity of the technique to various parameters, such as the number of subapertures, the length of the synthetic aperture, and the signal-to-noise ratio.