Clustering and Confidence Intervals for Radar Target Identification and Estimation

Ryan Volz*[1], Sigrid Close[1], and Philip J. Erickson[2]

[1] Stanford University, Aeronautics and Astronautics, Stanford, CA
[2] MIT Haystack Observatory, Atmospheric Sciences Group, Westford, MA

Pulsed radar data often presents the task of identifying targets and estimating their properties through use of a metric (data-derived, modeled, or hybrid) unique to the targets under study. Accuracy and reliability of this procedure is extremely important, especially since subsequent processing and scientific results can be inaccurate or misleading if target identification and estimation is flawed. For this reason, we present reliable methods for performing these processing steps and quantify their accuracy using real and simulated data.

When identifying targets, one must distinguish not only from noise but also from other targets or clutter. It is also important to recognize the same target as it evolves over time. These are easy but time-consuming and tedious tasks for a human operator, so one often seeks to automate this process. We describe a fast and general-purpose clustering approach that achieves these goals and results in very few false identifications in tested data sets. Potential signals are identified on a per-pulse basis by thresholding the SNR of the matched filter response with respect to range and range rate (Doppler shift). Clustering is performed in the three-dimensional space of range, range rate, and pulse time using a variant of the DBSCAN algorithm, with each cluster corresponding to the measurements for a single target.

Once one has targets, estimating their properties is the next step. The typical estimator for range, range-rate, and signal-to-noise ratio (SNR) based on finding the matched filter peak is known to be unbiased and efficient, achieving the Cramer-Rao lower bound for variance for large SNR or a large number of measurements. In practice, however, one faces many challenges. The data is sampled, so finding the continuous matched filter peak is a hard problem. Many targets of interest have low SNR or a limited number of measurements, so matched filter estimation will not achieve the Cramer-Rao bound. To address these problems, we formulate an estimator that uses quadratic interpolation to estimate the peak of the matched filter response, and we find the confidence intervals of this estimator using simulated data. The estimation procedure starts with locating the maximum amplitude of a discrete matched filter applied across both time delay (range) and Doppler shift (range rate). Then using the amplitudes of the surrounding points, one fits a convex paraboloid to the data and determines the peak of this paraboloid. The location of the peak gives estimates for range and range rate, while its value gives an estimate for SNR. Confidence intervals for this estimator from simulation results quantify the degree of trust we can place in the estimates when applied to real data.