Leveraging the High Dimensionality of AVIRIS Data for Improved Sub-Pixel Target Unmixing and Rejection of False Positives : Mixture Tuned Matched Filtering

Joseph W. Boardman
Analytical Imaging and Geophysics, LLC
Boulder, CO

boardman@aigllc.com

Much headway has been made by the direct application of the well-known signal processing technique of Matched Filtering to imaging spectrometry studies, especially applications involving detection and mapping of sub-pixel targets. The Matched Filter technique has long been used by electrical engineers for the detection of known signals in mixed backgrounds, especially in radio and radar applications. Its popularity derives from the proof that it is the optimal linear detector in such situations, maximizing the suppression of the background while simultaneously maximizing the target-to-background contrast. These dual properties make it appear to be the optimal detection method. However, in our case, the remote sensing mixed pixel case, it is most certainly not optimal. The underlying assumption of the "proof" used in radio and radar applications is one of unbounded superposition. Adding target signature in this case boosts the signal and one "hears" or "sees" the linear sum of the background and the target. This addition is wholly unbounded. In the imaging spectrometry case we have an undeniable and physically-meaningful bound on the signal: every pixel is only 100% full. As we add target material to a pixel it covers up some background, satisfying the unit-sum constraint. It does not add "area" to the pixel, as an additive radio signal adds "power" to its mixture. This simple but fundamental difference can be exploited to give an algorithm that then appears to have "super-optimal" performance, and shows the risk in a blanket application to remote sensing of techniques developed under different physical models and assumptions. We use these difference to our advantage in a technique called Mixture Tuned Matched Filtering (MTMF).

MTMF combines the best parts of the Linear Spectral Mixing model and the statistical Matched Filter model while avoiding the drawbacks of each parent method. From Matched Filtering it inherits the advantage of its ability to map a single known target without knowing the other background endmember signatures, unlike traditional Spectra Mixture modeling. From Spectral Mixture modeling it inherits the leverage arising from the mixed pixel model, the constraints on feasibility including the unit-sum and positivity requirements, unlike the Matched Filter which does not employ these fundamental facts. As a result MTMF can outperform either method, especially in cases of subtle, sub-pixel occurrences. In fact, using MTMF we have found a previously undetected, and very subtle, occurrence of ammonium minerals at the heavily studies site of Cuprite, Nevada! The MTMF method leverages the high dimensionality of AVIRIS data, using the high dimensional space to its advantage, to greatly increase detectability and selectivity. Sub-It routinely demonstrates single 3% to 5% abundance sub-pixel occurrences along with outstanding false-positive rejection and target selectivity. Question proofs of optimality.