Kronecker PCA Based Space-Time Adaptive Processing

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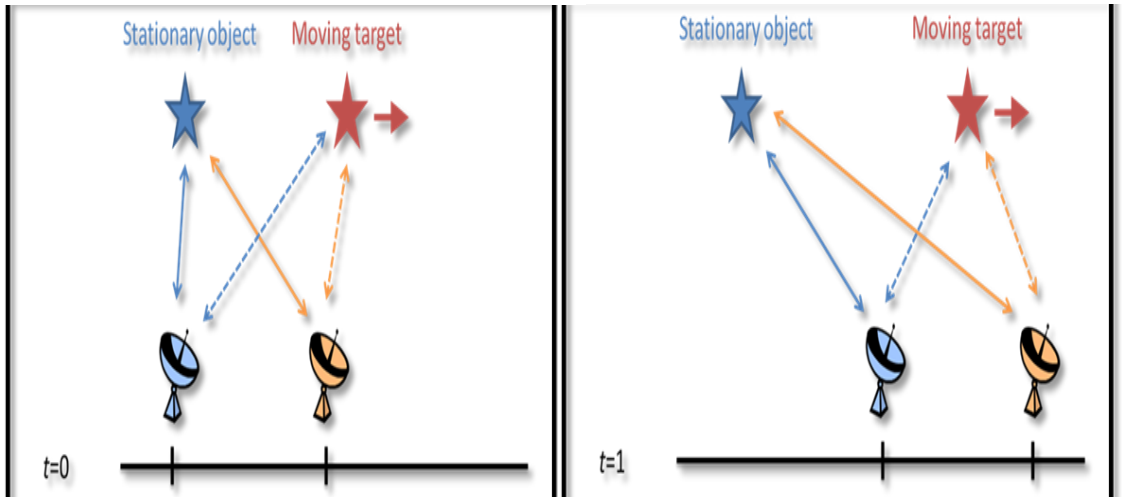
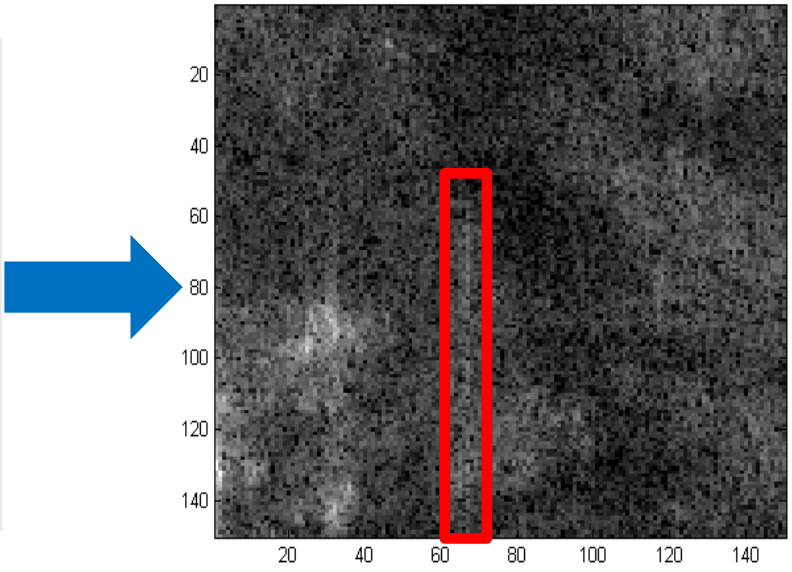
SAR and GMTI

- Goal: Detect moving targets in multiantenna SAR.
- Classical GMTI radar (Doppler based) has minimum detection speed and low resolution.
  - Low frequency, short integration time
- Synthetic Aperture Radar (SAR) excellent at detecting stationary targets and has high resolution. No MDV.
- SAR: smears moving targets, hence “buried” in clutter.





KronPCA STAP

- SIRV model for observed range bin x ($pq \times 1$) across p channels and q pulses (all zero mean):

$$x = x_c + x_{noise} + x_{targ}$$

- Subspace model: Clutter image (arranged as channel vs. pixel) ideally **lives in 1D subspace.**

$$x_c = \alpha\beta^T$$

  where α is across channels and $\beta = \tau\gamma$ (random SIRV)

- Goal: design filter A (using training examples) to cancel clutter:

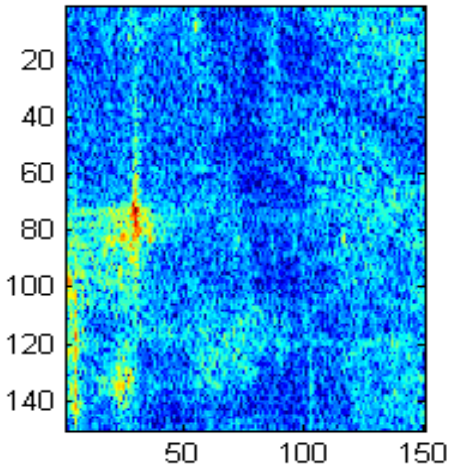
$$y = Ax$$

- **Standard approach:** Project onto principal components of sample covariance.
- **Kronecker PCA approach**: under the rank one model, the clutter + noise covariance should be (more Kronecker terms if interference):

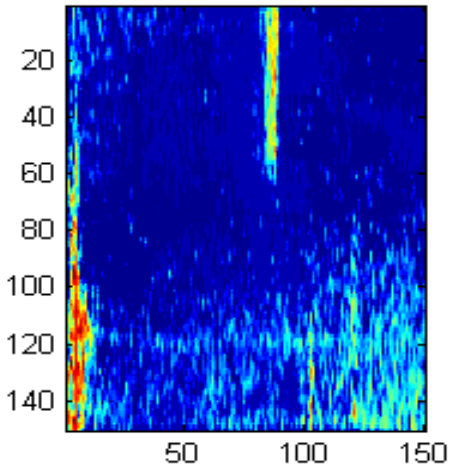
$$\Sigma_c = T \otimes S, \qquad T = \alpha\alpha^T$$
$$\Sigma = E[\tau]T \otimes S + \rho I$$

Results

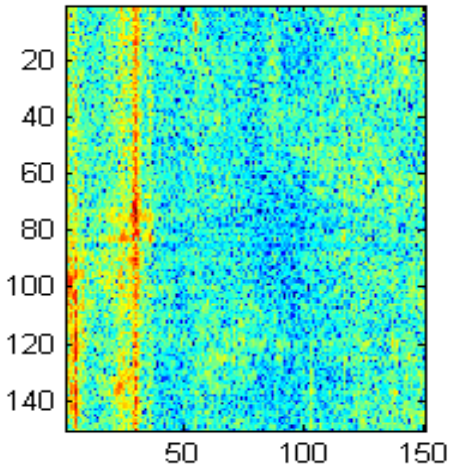
- Iterative shrunk maximum likelihood (Kronecker SIRV) algorithm.
  - Outlier mitigation. Allows **moving targets to be included in training**.
  - Provably far fewer training samples required than SCM.
- Public release Gotcha GMTI challenge dataset. $p = 3$ antenna channels; circular SAR. Used ~1 second integration time.
- KronPCA STAP with cancelation estimation vs. standard low rank STAP.



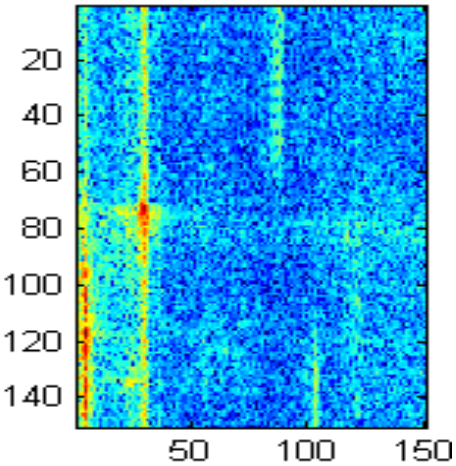
Raw Image



KronPCA STAP



Standard STAP (few)



Standard STAP (many)

References

1. K. Greenewald, A. Hero, “Regularized Block Toeplitz Covariance Matrix Estimation via Kronecker Product Expansions,” in *IEEE SSP*, 2014.
2. K. Greenewald, T. Tsiligkaridis and A. Hero, “Kronecker Sum Decompositions for Space-Time Data,” in *IEEE CAMSAP*, 2013.
3. T. Tsiligkaridis and A. Hero, “Covariance Estimation in High Dimensions via Kronecker Product Expansions,” *IEEE Transactions on Signal Processing*, 2014.
4. T. Tsiligkaridis, A. Hero, and S. Zhou, “On convergence of kronecker graphical lasso algorithms,” *IEEE Transactions on Signal Processing*, vol. 61, no. 7, pp. 1743–1755, 2013.
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7. Gotcha GMTI dataset, AFRL SDMS https://www.sdms.afrl.af.mil/index.php?collection=gmti.