University Defence Research Collaboration (UDRC) Signal Processing in a Networked Battlespace

(Related project)

E_WP2: Multistatic Single Data Set Radar Detection in Coloured Gaussian Interference

WP Leader: Prof. Bernard Mulgrew*, University of Edinburgh*
Researcher: Bogomil Shtarkalev

Abstract: Space-time adaptive processing (STAP) for radar perform target detection in spatio-temporal coloured interference. Traditional detectors rely on target-free training data to form an estimate to the interference covariance matrix. The maximum likelihood estimation detector (MLED) and its generalised counterpart (GMLED) perform covariance estimation and target detection on the single data set in the cell under test (CUT). In this work we extend the algorithms to a multistatic scenario where a multiple-input multiple-output (MIMO) radar system with spatial diversity gains. We show that the proposed algorithms are comparable in performance to the existing methods that need a training data set to perform detection.

Signal Model

Arrange the STAP observations from the CUT into the matrix $\boldsymbol{X}_{m,n}$ of iid snapshots:

$$\begin{aligned} H_0 &: \boldsymbol{X}_{m,n} = \boldsymbol{N}_{m,n} \\ H_1 &: \boldsymbol{X}_{m,n} = \alpha \boldsymbol{s}_{m,n} \boldsymbol{t}_{m,n}^T + \boldsymbol{N}_{m,n} \end{aligned} \tag{1}$$

Given an observation set $\boldsymbol{X}_{m,n}$, a set of known parameters $\boldsymbol{\Psi}$, and a set of unknowns $\boldsymbol{\chi}$, an ML detector maximises the likelihood ratio between the two hypotheses (1)

$$\frac{\max_{\boldsymbol{\chi}_1} p(\boldsymbol{X}|\boldsymbol{\Psi}_1)}{\max_{\boldsymbol{\chi}_0} p(\boldsymbol{X}|\boldsymbol{\Psi}_0)} \underset{H_0}{\overset{H_1}{\gtrless}} \gamma \tag{2}$$

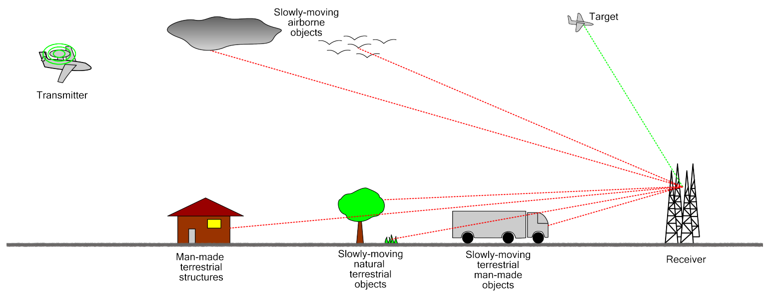

Figure 1: Sources of background interference and clutter in bistatic radar

Current Estimation Algorithms

Two Data Set (TDS) Detection

- Usually ML sample covariance inversion (SMI) algorithms: AMF, GLRT
- Use neighbouring range gates as secondary data to form interference covariance estimate
- Impractical in a heterogeneous or target-rich environment

Subspace Projections Detection

- Based on separating the interference subspace from the target subspace
- Projecting interference out of observation data
- No need for covariance estimation or SMI, can work with a single data set
- Require full knowledge of the interference subspace location

Single Data Set Detection

SDS Advantages

- Can operate in heterogeneous an/or non-stationary environment
- No training data required

The MLED/GMLED Detectors

- Combine subspace projections and SMI-based detectors
- Project potential target of known template from observation signal $\boldsymbol{X}_{m,n}$
- Estimate an interference covariance matrix from the leftover signal
- Robust, CFAR detectors that can operate with no prior knowledge on environment

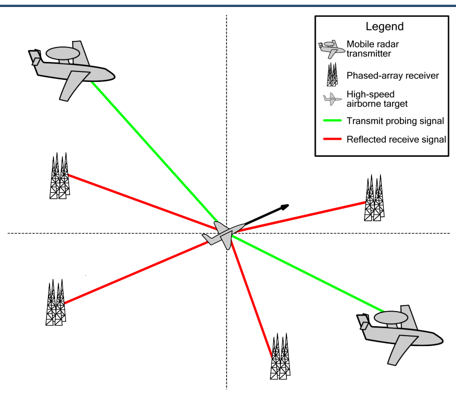

Figure 2: Multistatic radar scenario

Multistatic SDS Detection

- The MLED/GMLED have been extended to a multistatic scenario
- Multiple transmitters and receivers scan an area for potential targets (fig. 2)
- Non-coherent ML fusion of results provides statistical gains in detection

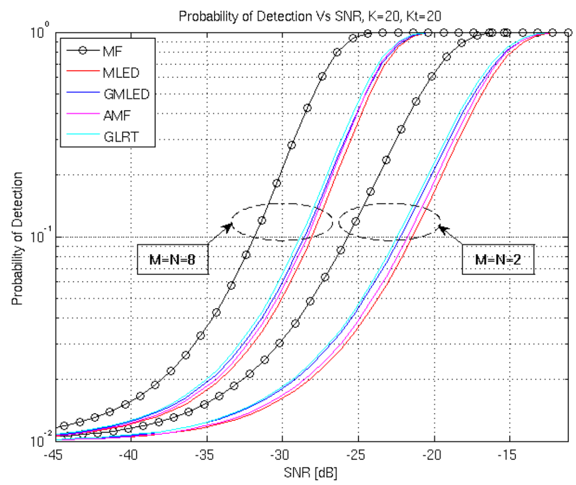

Figure 3: Probability of detection vs SNR for 20 observation signal snapshots and 20 training data snapshots

Conclusion: We have developed two multistatic ML target detectors based on SMI that perform detection and estimation on a single observation data set. We have shown that these two detectors are comparable in performance to existing TDS algorithms that require significantly more input that may be impossible to obtain in a heterogeneous environment. Our proposed detectors are CFAR and benefit from the statistical diversity of multiple independent observations of a moving target.

Future Work: Currently the proposed detection algorithms fuse their ML estimation variables in one node before detection is performed. Future work will be devoted to making the proposed algorithms distributed so that node-to-node communication in a large network is limited to a small neighbourhood.

THE UNIVERSITY *of* EDINBURGH