Technion – Israel Institute of Technology
Department of Electrical Engineering
Signal and Image Processing Lab

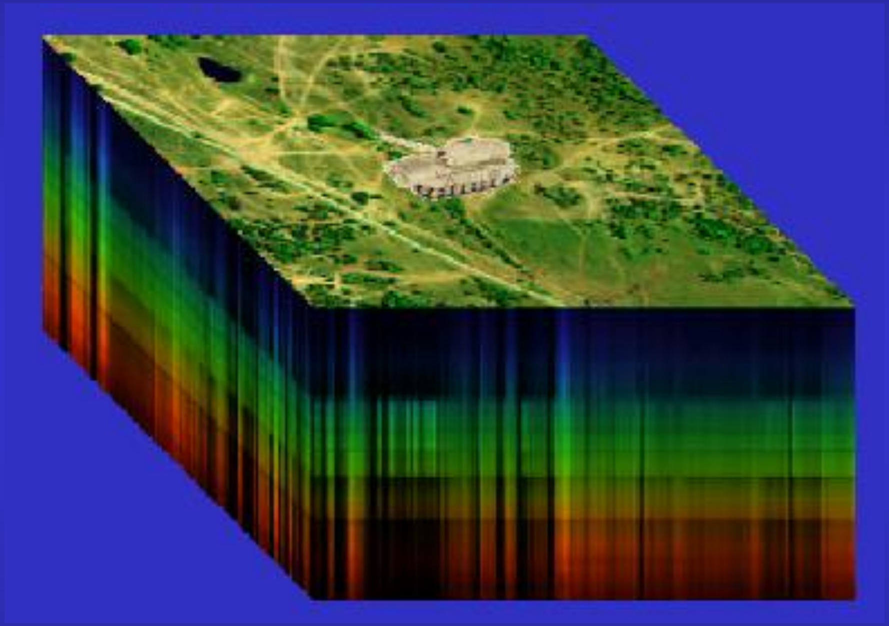
Anomaly Detection in Hyperspectral Images

Ayal Hitron and Boaz Matalon

Supervised by
Asaf Cohen and Dr. Ruti Shapira

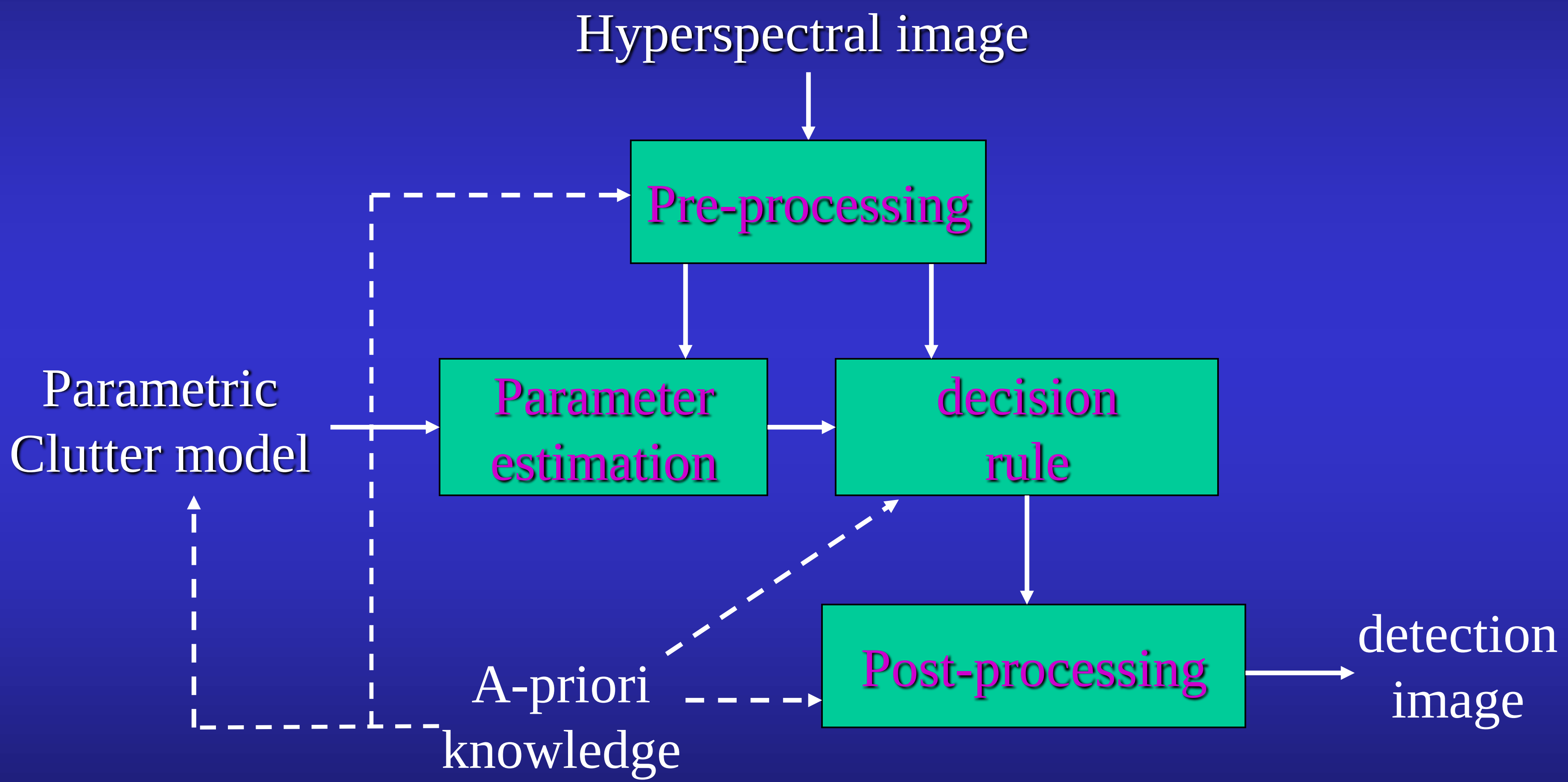
In cooperation with Rafael

Introduction: Hyperspectral Images



Anomaly – a man-made object surrounded by natural clutter

Adaptive Anomaly Detection



Local Anomaly Detectors

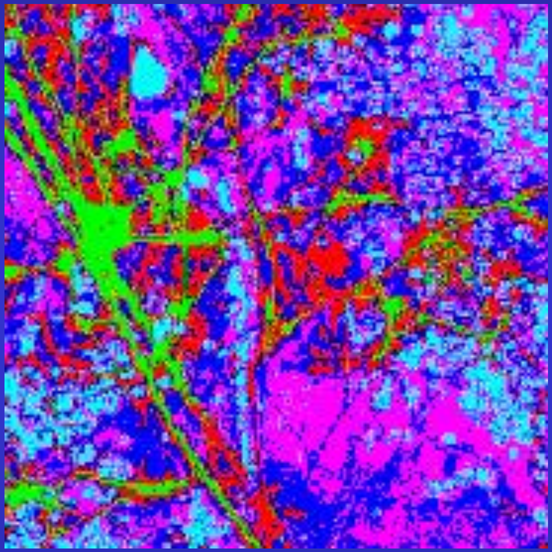
- After local mean removal, clutter is spatially-stationary within a small-enough processing window.

Parameter estimation:

- Using reference data
- Binary Hypothesis approach

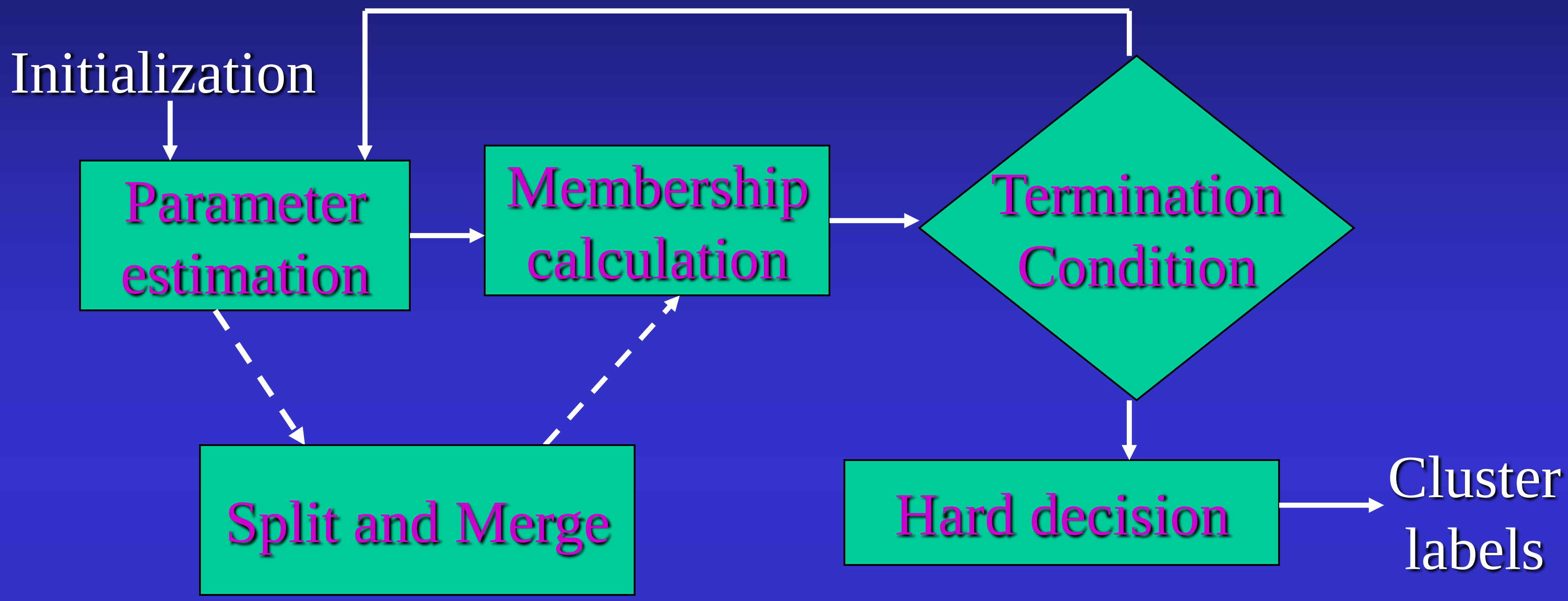
Global Anomaly Detectors

Gaussian Mixture Model (GMM)



- Clutter is spatially-stationary within each cluster
- Parameter estimation employing the entire image, neglecting the effect of anomalies

Iterative Clustering Algorithms



- Maximization of an optimality function
- Fuzzy clustering: fractional degrees of membership
- Criteria for optimal number of clusters

Main clustering algorithms

Algorithm is determined by the calculation of pixel-cluster membership degree

- Euclidian distance from centroids (K-means, fuzzy K-means, ISODATA)
- A-posteriori probability (EM, CEM, SEM, ICM)

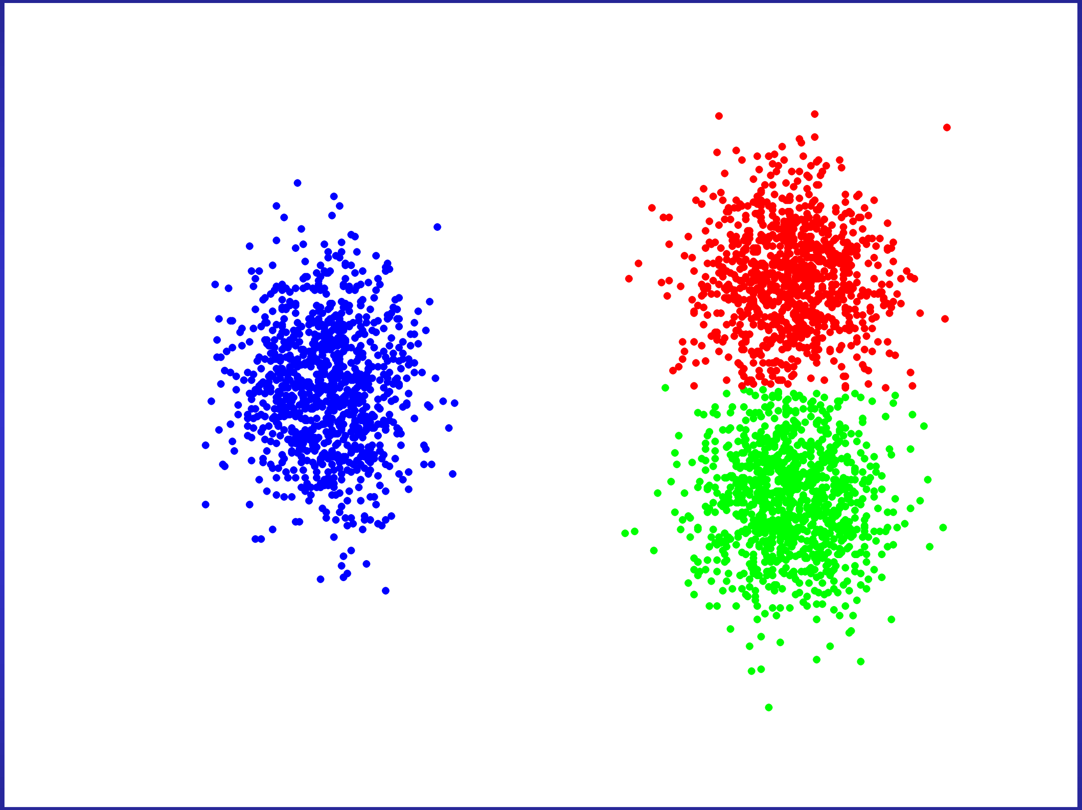
Parameter estimation:

- Maximum likelihood (ML)
- Fuzzy maximum likelihood (FML)

Split & Merge

Splitting Criteria:

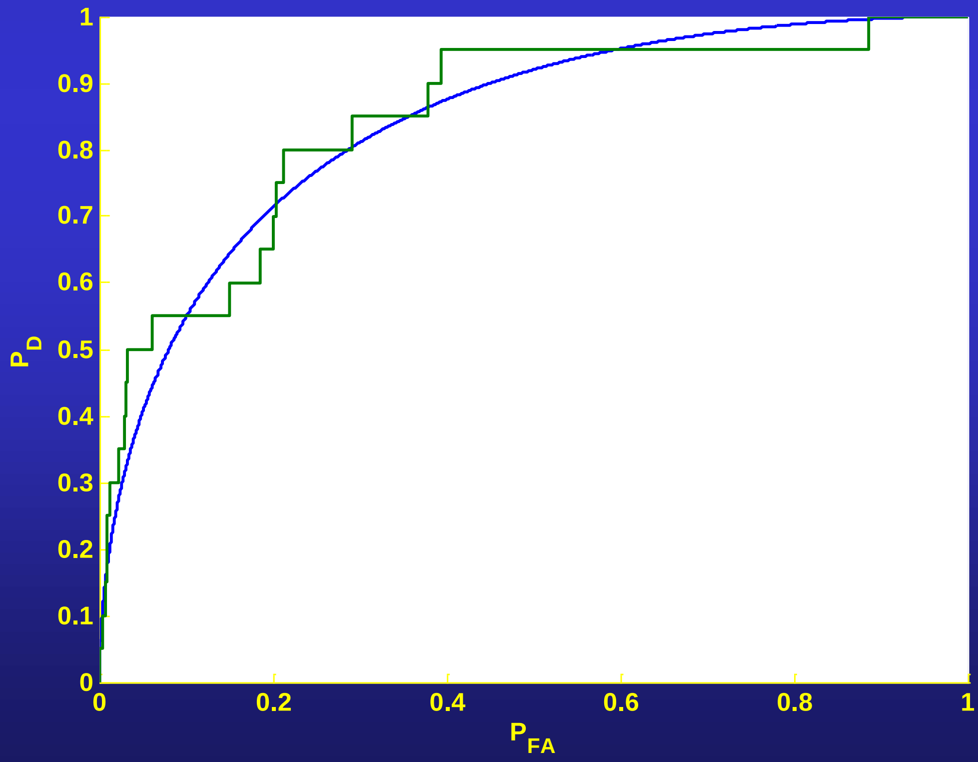
- Kurtosis
- Fourth moment
- First moment
- Major axis length
- Condition number



Performance Evaluation

Receiver Operation Characteristics (ROC):

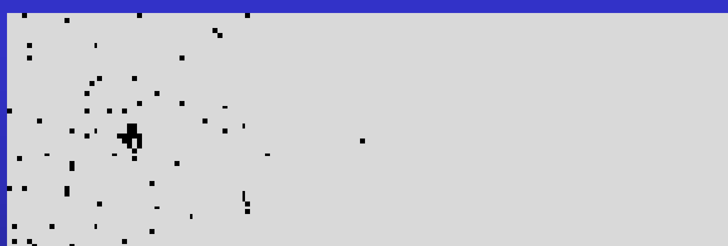
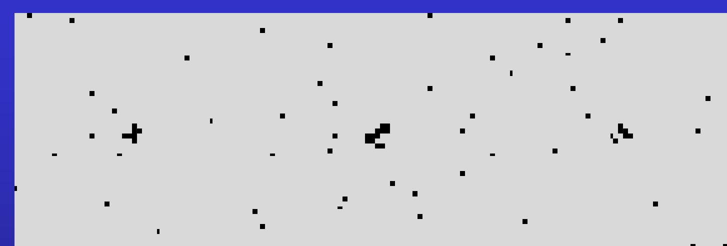
- Detection and false-alarm probabilities (P_D , P_{FA})
- Theoretical vs. Empirical performance evaluation



Constant False Alarm Rate (CFAR)

Prior to threshold-comparing:


After threshold-comparing:

- More reliable detection and performance evaluation
- Non-trivial property

Utilizing a-priori knowledge

Binary Hypothesis (BH) detector:

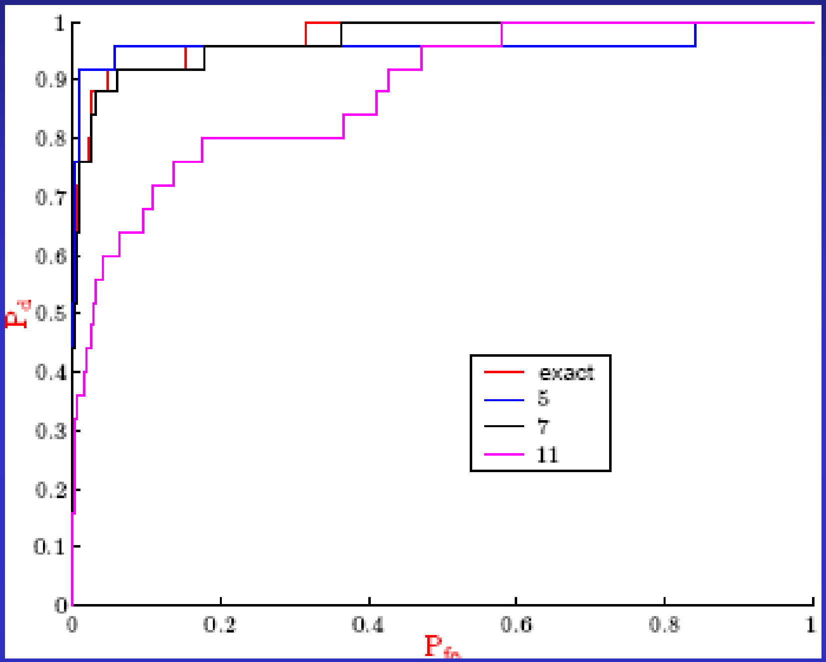
- Parametric target model: known shape and/or spectrum
- Generalized likelihood ratio test (GLRT)

$$\frac{\max_{S,\theta} P(X \mid S,\theta,H_1)}{\max_{\theta} P(X \mid \theta,H_0)} \overset{?}{>} \eta$$

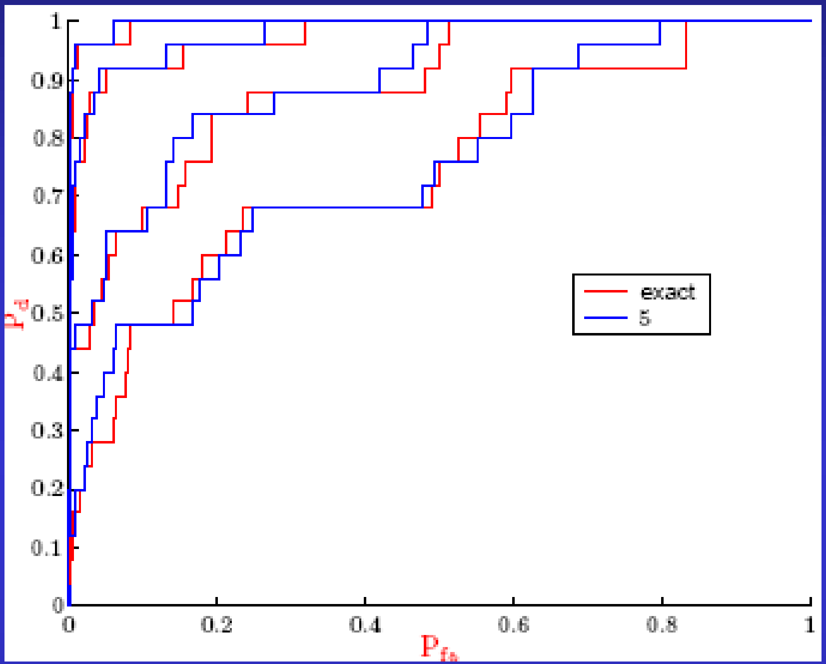
Pre-processing: band reduction

Post-processing: morphological operations

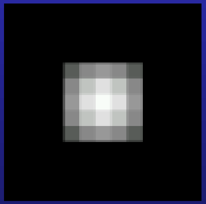
Incorrect Shape Assumption



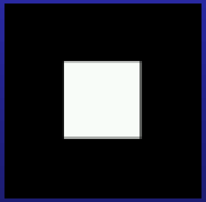
(various sizes)



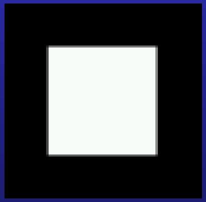
(size of 5x5)



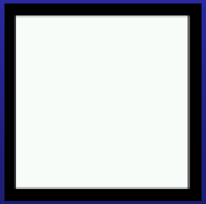
5x5Gaussian



5x5 square



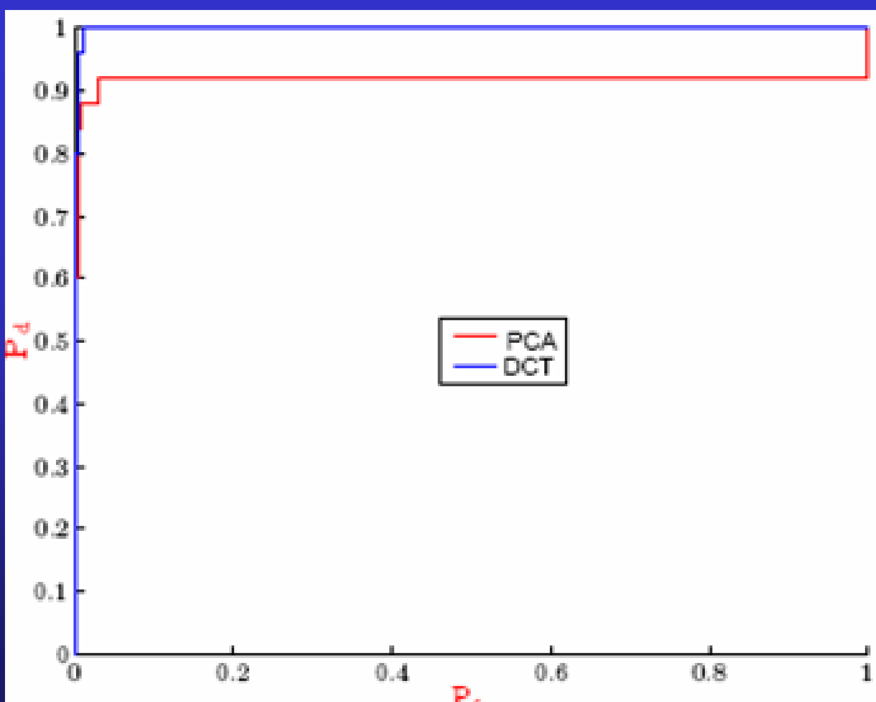
7x7 square

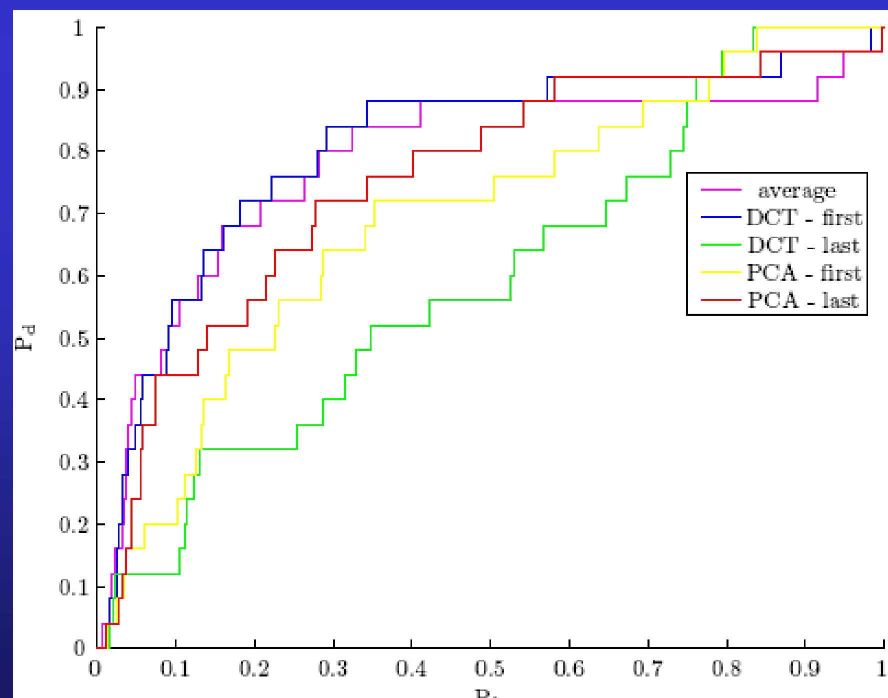


11x11 square

Band Removal Methods

- After clustering, the number of bands may be reduced.
- Several methods exist: Averaging, PCA and more.
- We proposed the DCT, which has an advantage when the Global BH detector is used.

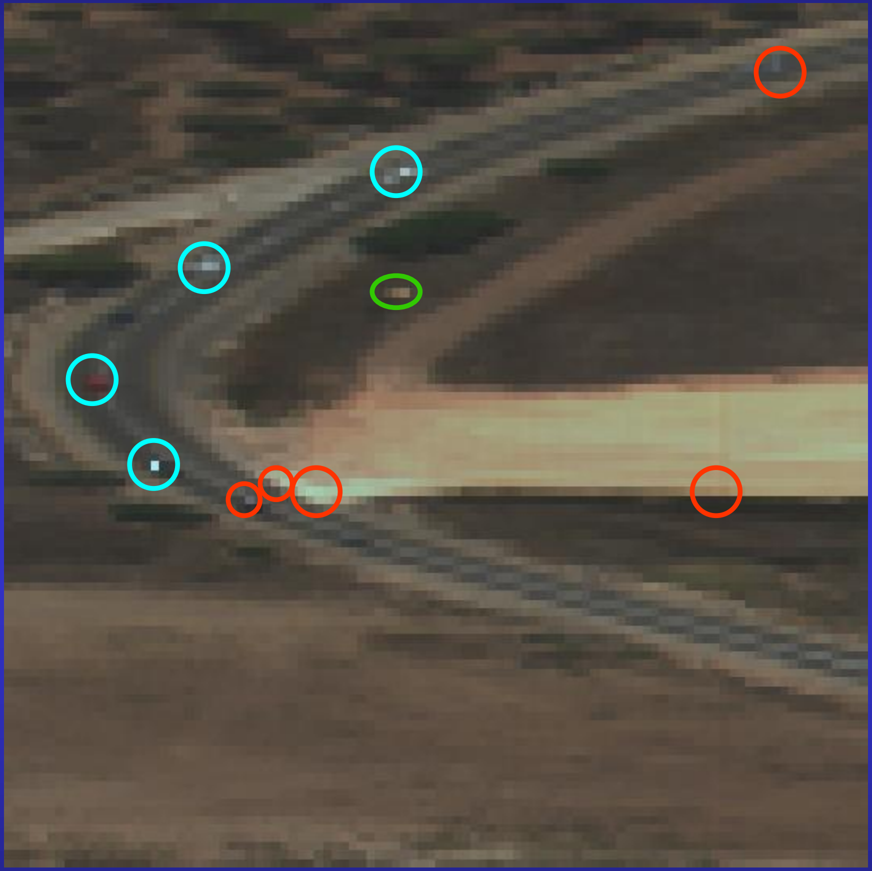


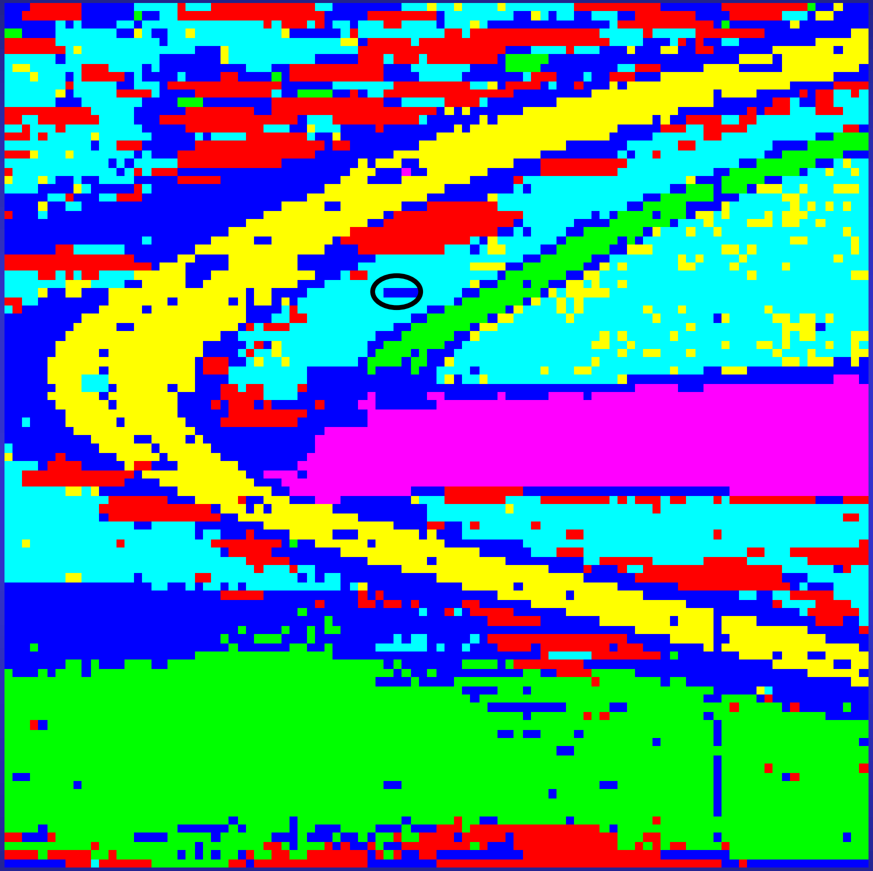


Survey of Detection Algorithms

- RX [Yu and Reed, 1990]
- Local GMRF [Schweizer and Moura, 2000]
- Global Single-Hypothesis
- Global Binary-Hypothesis
- Single-Hypothesis RX
- Fuzzy detection

An Example





Main Conclusions

- If target’s size is known approximately, a BH approach is recommended
- If the picture has several distinct clusters, the detector should possess the CFAR property
- If the picture is known to be piecewise smooth, use clustering which prefers homogenous clusters, e.g. ICM
- One cannot detect all types of anomalies at once, since each detector has its own model. Combining several approaches may increase performance

Our Contributions

- Developing a Global BH detector with the CFAR property.
- Theoretical performance evaluation of the Global BH detector with known spectral signature.
- Theoretical performance evaluation of the Global SH detector with a smoothing filter.
- Introducing the DCT transform as a band reduction method, which can outperform the PCA method.
- Introducing and implementing a Fuzzy detector.

The End