Non-Gaussian Background Modeling for Anomaly Detection in Hyperspectral Images

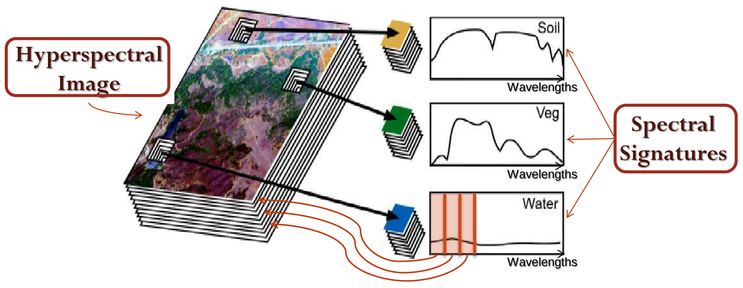
Eyal Madar, Pr. David Malah, Dr. Meir Bar-Zohar

Signal and Image Processing Laboratory (SIPL), Dept. of Electrical Engineering, Technion - IIT

1. Problem Description

○ Hyperspectral Image

- Each pixel corresponds to a spectral signature (spectrum) reflected from the pixel location
- Each material can be characterized by its spectrum



○ Anomaly Detection

- Prior anomaly signatures are unknown
- Method:
  1. First, model the background
  2. Then, detect anomalies by finding pixels that are not well-described by the background model

○ Statistical Background Modeling

- Local approach:

  The background is modeled by a large number of local independent distributions. Subject to overfitting. Generally based on the Gaussian distribution.
- Global approach:

  Based on a global representation of the background process in the whole image. Subject to underfitting.

2. Proposed Solution: NG-BEVA

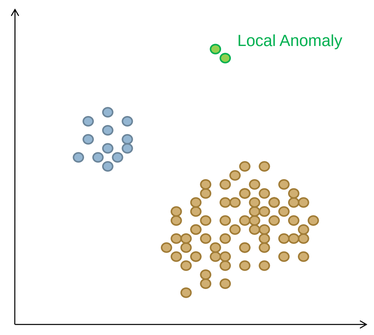
○ Non-Gaussian Background Extreme Value Analysis :

- "Local-global" statistical background modeling approach
- No Gaussian assumption is made.

2.1. Local Part

○ Local background model

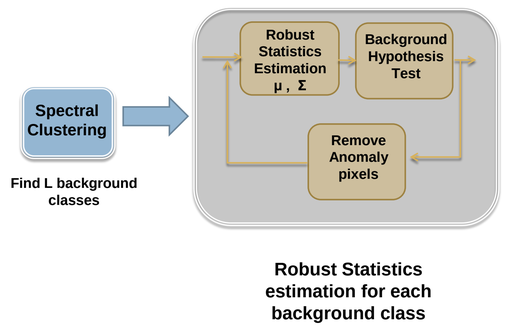
- The hyperspectral image is partitioned into distinct local block
- Each local block is composed of L distinct clusters (up to 3)



Local Background Model

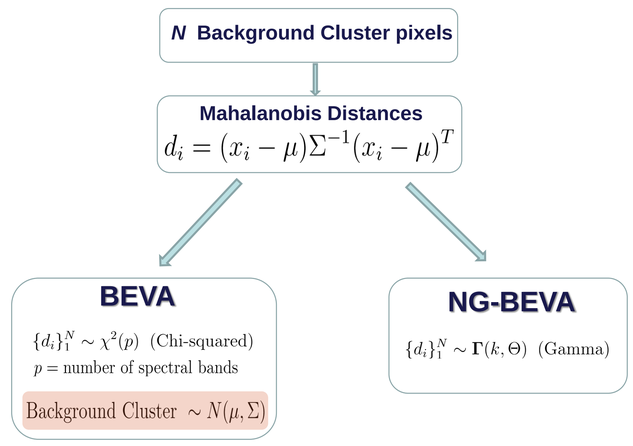
○ Local background model estimation

- Clustered using the Spectral Clustering Algorithm
- Estimate the statistics of each background cluster by using a greedy iterative estimation process based on Extreme Value Theory results for the Gamma distribution



Robust Statistics estimation for each background class

○ Mahalanobis Distance Statistics



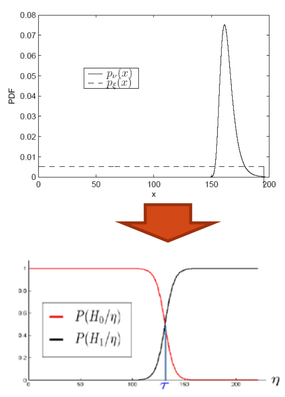
○ Background Cluster Hypothesis Test

Distribution of υ

Given by extreme value statistics of maximum Gamma realizations:

$$P(\upsilon \le x) = G(a_{p,N}(x - b_{p,N}))$$

$$G(x) = e^{-e^{-x}} \quad \text{(Gumbel distribution)}$$

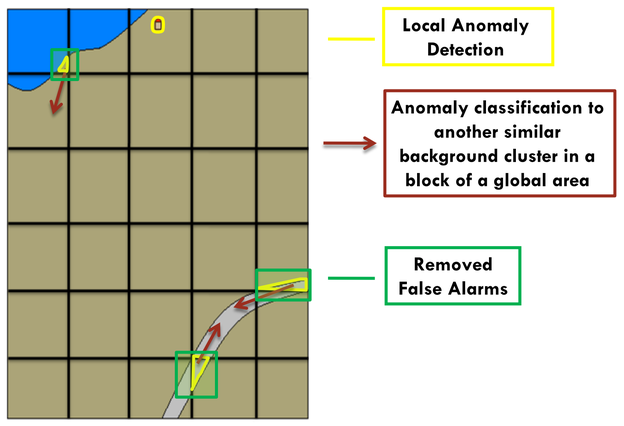


Distribution of ξ

Assumed to be uniformly-distributed

2.2 Global Part

- Pixels are compared to a "dictionary" where each "word" consists of estimated local background cluster statistical parameters



3. Results

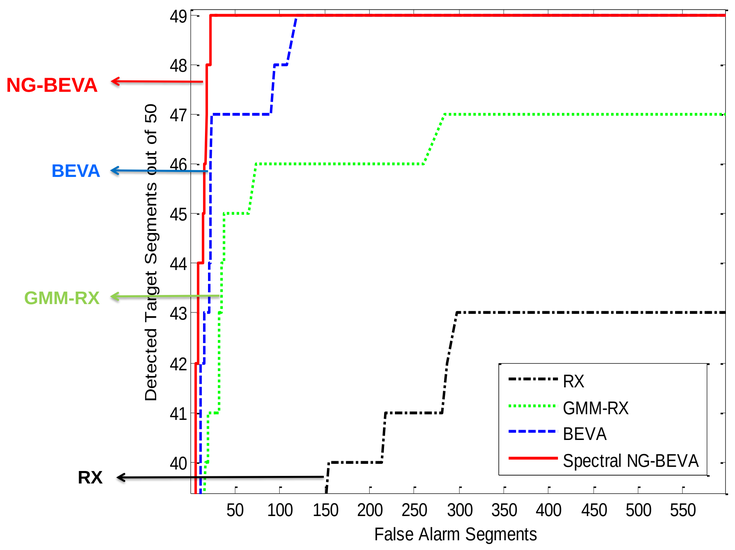
3.1. Dataset

- AISA airborne sensor
- 5 real hyperspectral image cubes (1.2km2)
- 65 spectral bands (400-1000nm)
- 50 anomalies (vehicles and small constructions)

Manually identified ground-truth anomalies, marked in red and encircled by ellipses.

3.2. Comparative Results

- Detected targets versus False Alarm segments:



- Computation Time:

Data

- 350x350
- 65 bands

Computer

- Intel Core 2 duo 2Ghz
- 2 GB Ram
- Environment - Matlab©

RX	770 sec
GMM-RX	27 sec
BEVA	61 sec
NG BEVA	491 sec

4. Conclusion

○ NG-BEVA:

- Based on a local-global statistical background modeling.
- Reduces the vast number of degrees of freedom while retaining the ability to be locally adjusted to the background.
- No Gaussianity assumption is made
- Outperforms both standard local and global algorithms.