Technion

SIGNAL & IMAGE PROCESSING LAB

SIPL

LOCAL-GLOBAL BACKGROUND MODELING FOR ANOMALY DETECTION IN HYPERSPECTRAL IMAGES

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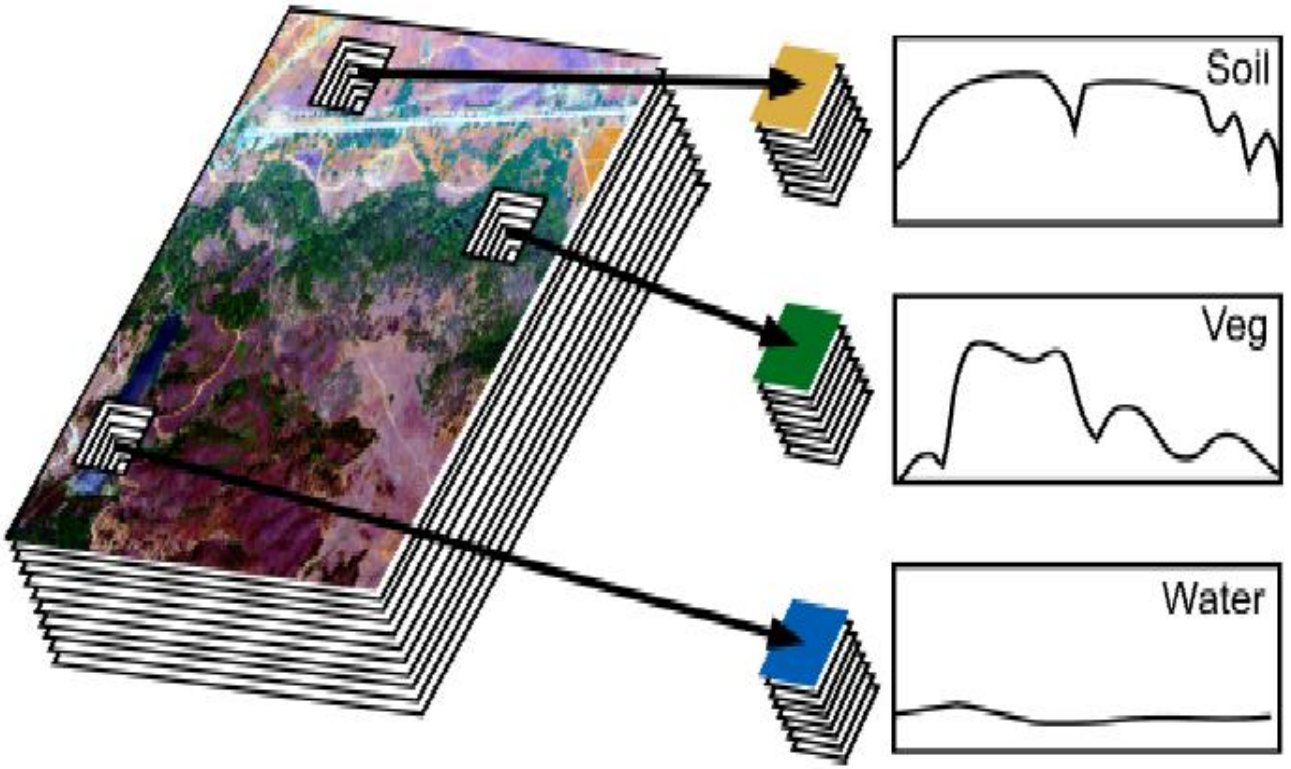
Outline

- Hyperspectral Imaging
- Statistical Background Modeling
  - Local Approach
  - Global Approach
- Combined Local-Global Approach
- Proposed Algorithm
  - Local Part
  - Global Part
- Experimental Result

Hyperspectral Imaging

Image Acquisition



Detection in Hyperspectral Imaging

Unsupervised Detection

- Prior anomaly signatures are unknown

- Anomaly detection methods:
  - Model the background
  - Detect anomalies by finding pixels that are not well-described by the background model

- *Statistical Background Modeling*
  - Local approach
  - Global approach

Local Approach

- ***Principle***

  Background is estimated in a local neighborhood of a tested pixel.

- ***Advantages***

  Due to the *many degrees of freedom*, local background models can be tightly fitted to the background data.

- ***Problem***
  - Too high number of degrees of freedom may cause model *overfitting.*
  - Insufficient data for parameters estimations of complex local models

Global Approach

- ***Principle***

  Background modeling is based on the entire image.

- ***Advantages***

  Robust estimation and more resistant to the overfitting problem.

- ***Problem***
  - Limited ability to adapt to all nuances of the background process (*underfitting problem*)
  - Difficult optimization process with a lot of local minimums

Combined Local-Global Approach

- ***Goal***

  Significantly improve detector performance by a proper combination of the local and global background modeling principles.

- ***Proposed Algorithm***

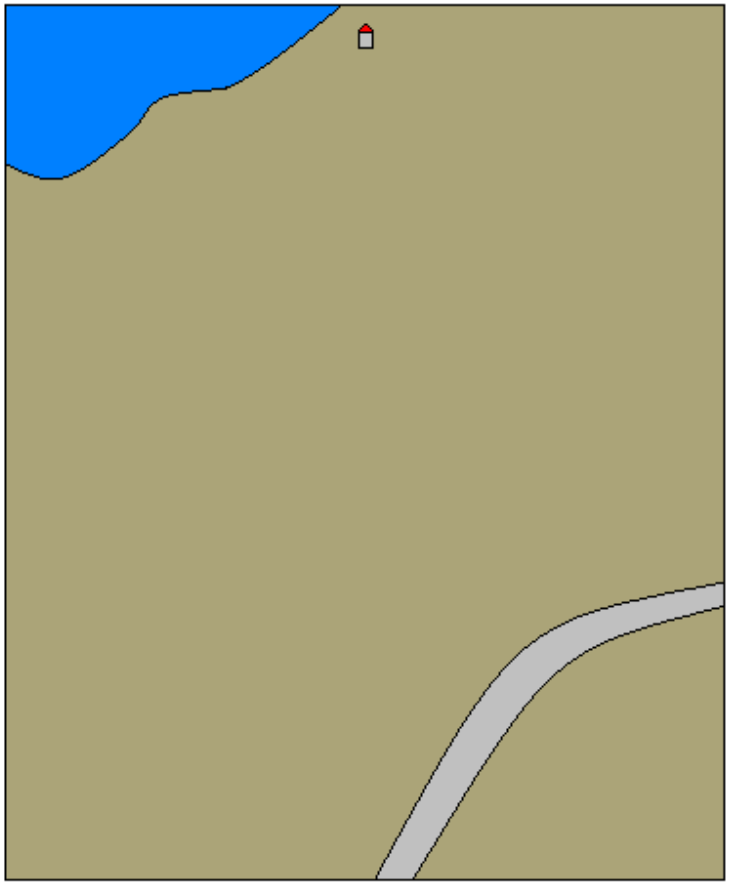
  Local part:

  - Greedy sequential estimation process
  - Robust Gaussian statistics estimation
  - Background cluster hypothesis testing based on extreme value theory results

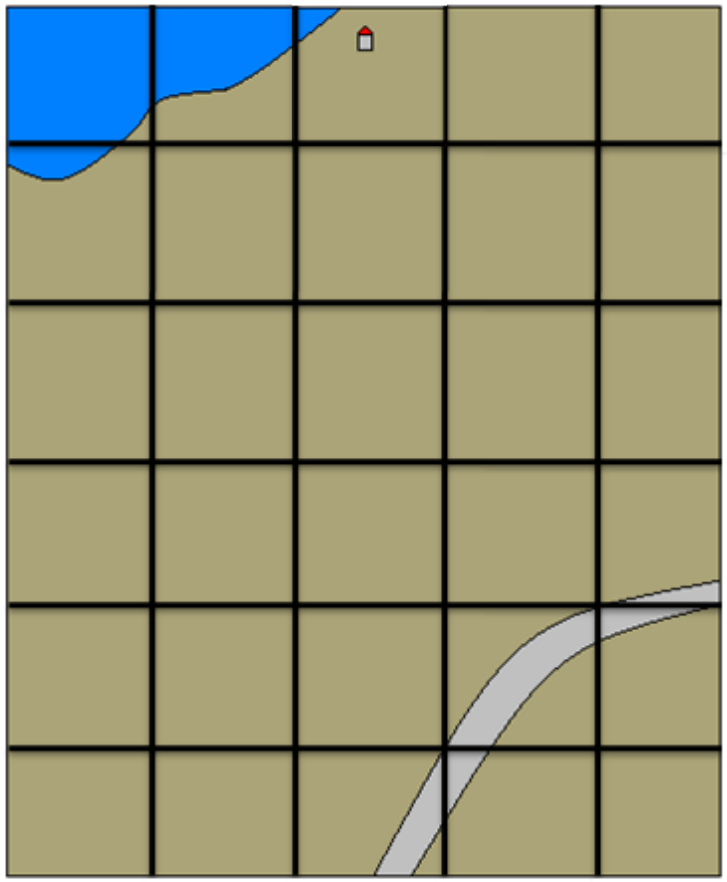
  Global part:

  - Global filtering which reduces the number of degrees of freedom

A combined local-global algorithm



A combined local-global algorithm



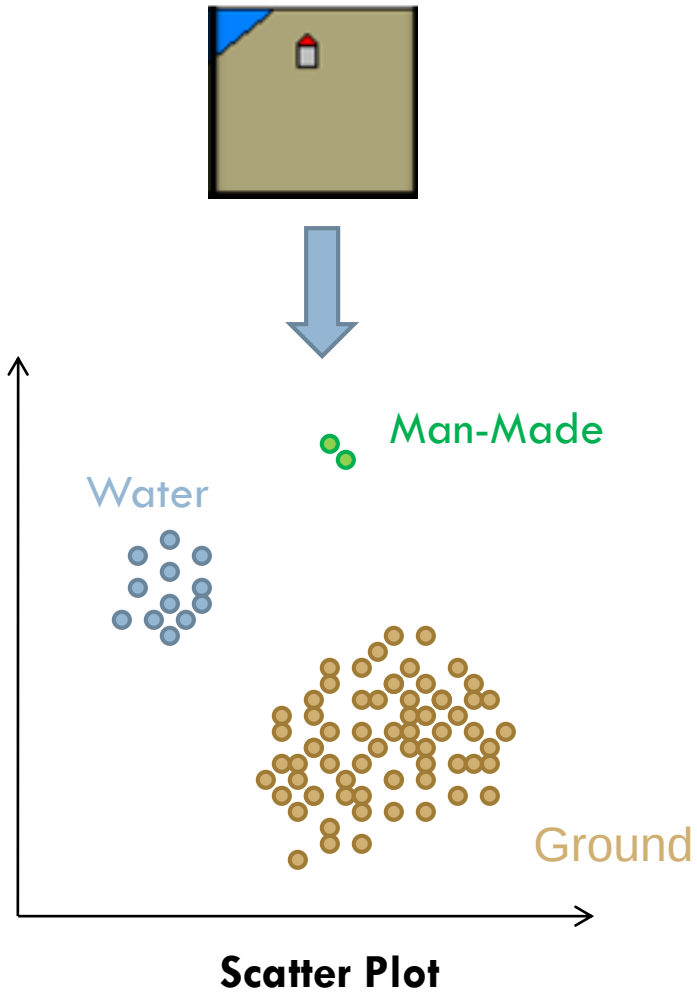
Local Part

Assumption

- **Local assumption:**

  The local background model is composed of a small number of distinct clusters ,L, *(up to 3), ordered by size, each distributed* as a separate Gaussian distribution.

$$\begin{cases} x \in C_k, \quad 1 \le k \le L \\ C_k \sim N(\mu_k, \Gamma_k) \\ |C_1| \ge |C_2| \ge \cdots \ge |C_L| \end{cases}$$



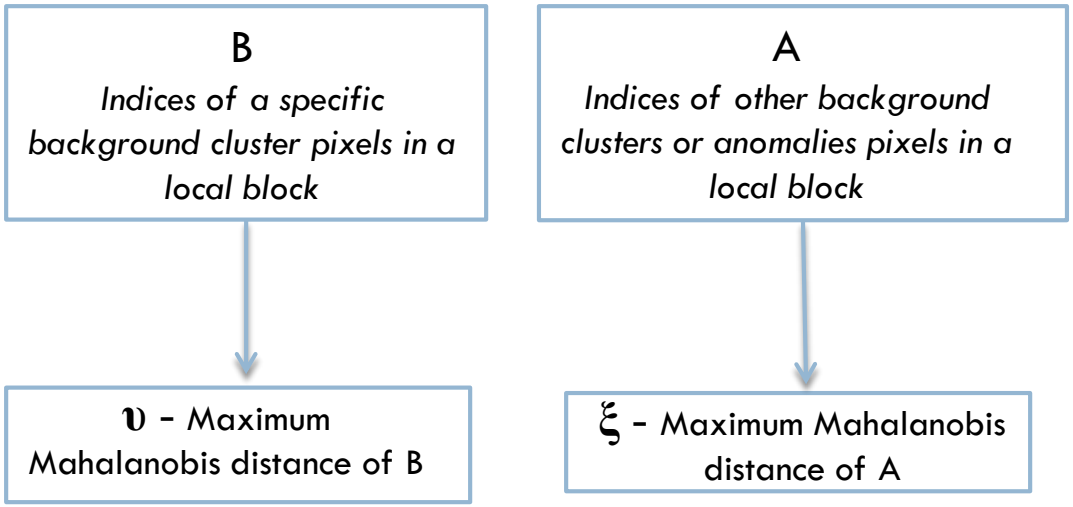
Background cluster hypothesis test (1)

- **Goal**

  An automatic test that isolates pixels belonging to a specific background cluster in a local image area.

- **Assumption**

  The cluster statistics (Gaussian mean and covariance) are known



Background cluster hypothesis test (2)

- **Distribution of υ**

  Given by extreme value statistics of maximum-norm Gaussian realizations:

  $$P(\upsilon \le x) = G\left(a_N\left(x - b_N\right)\right)$$

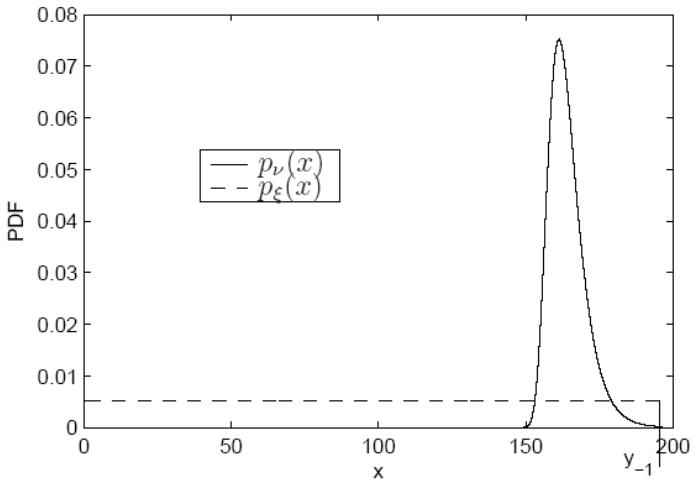
  with

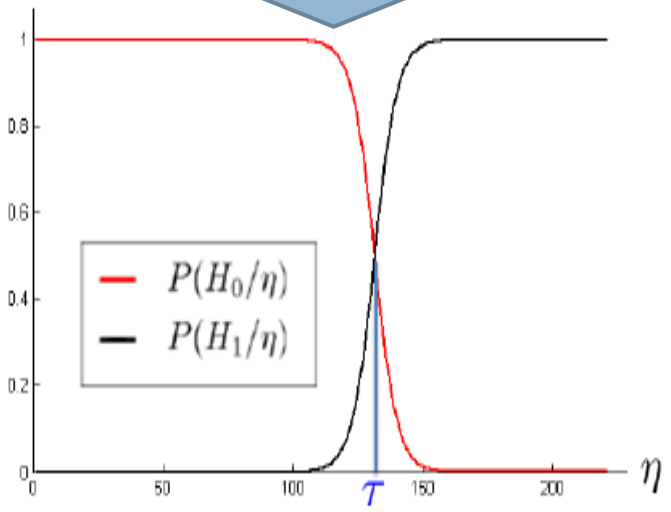
  $$G(x) = e^{-e^{-x}} \ (Gumbel\ distribution)$$

- **Distribution of ξ**

  Assumed to be uniformly-distributed

  $$\xi \sim U(0, \eta)$$





Local Part
Algorithm

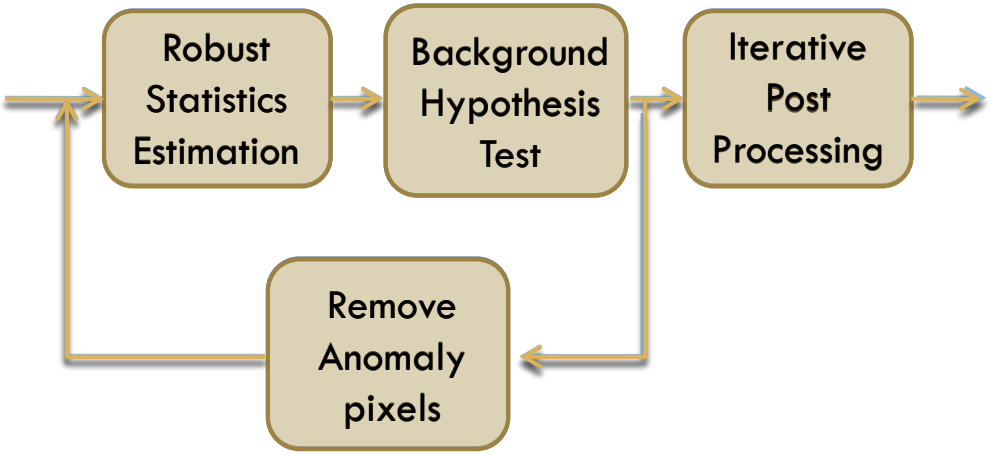
- **Main Loop :**

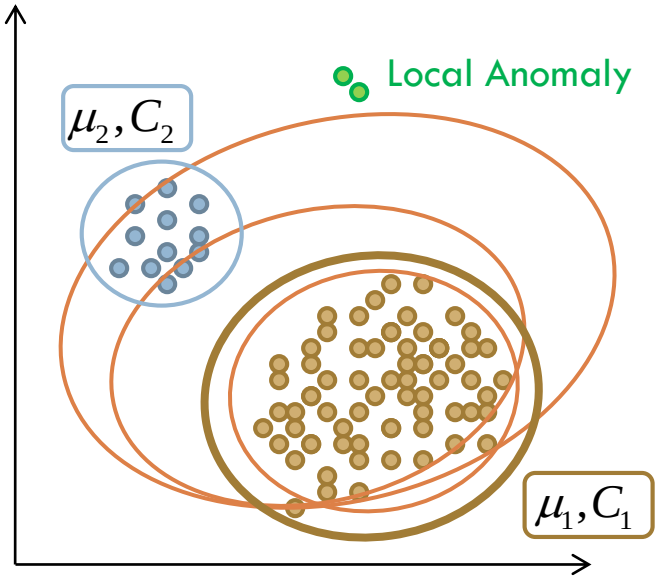
  An intermediate set B_{tmp} exclusively composed of pixels of the dominant background cluster is obtained.

- **Post Processing:**

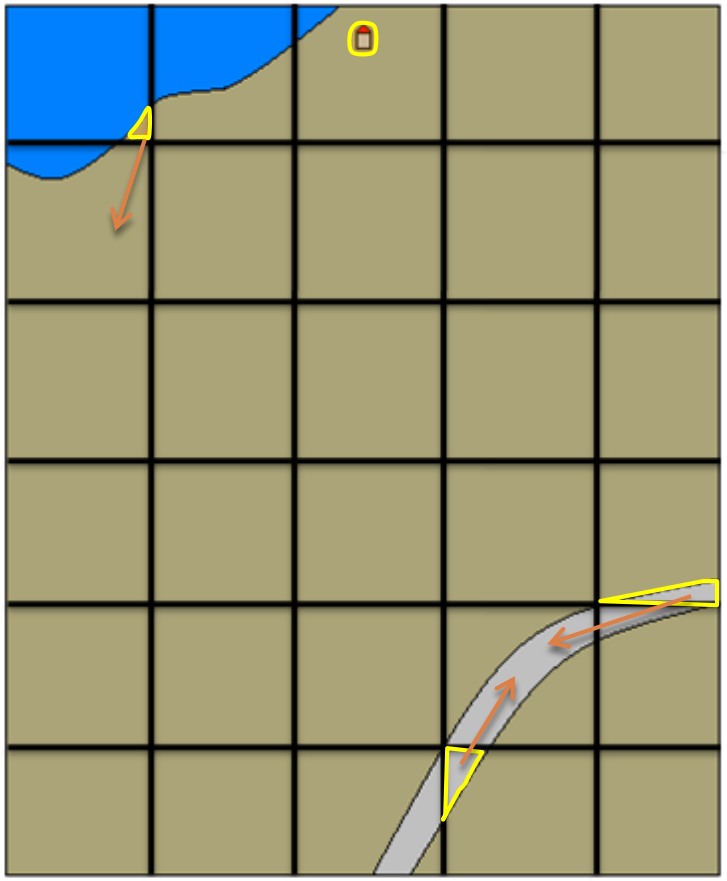
  Re-introduce the excluded pixels back into B_{tmp}

- **Result:**
  - Clusters statistics estimation
  - Pixel classification (local anomalies)





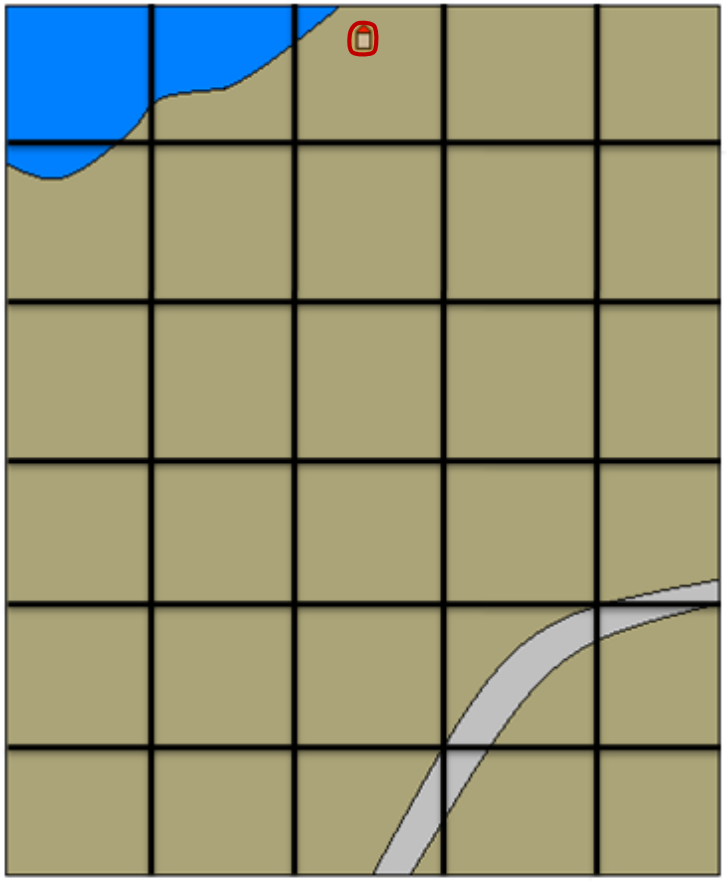
Global Part



Anomaly classification to another similar background cluster in a block of a global area

Local Anomaly Detection

Global Part

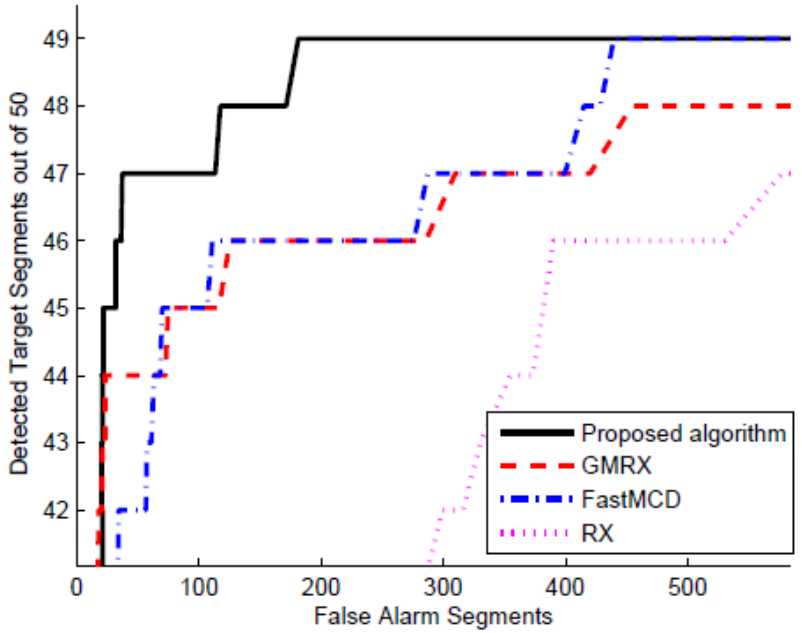


Global Anomalies

Experimental Results

- **Data:**
  - AISA airborne sensor
  - 5 real hyperspectral image cubes (1.2km^2)
  - 65 spectral bands (400-1000nm)
  - 50 anomalies (vehicles and small constructions)

- **Algorithm:**
  - Local block size 40x40
  - Global block size 400x400



Summary

- ***Combined Local-Global proposed algorithm***
  - Local – Greedy sequential estimation process
  - Global – Filtering using large image area statistics

- ***Advantages of the new approach***
  - Reduces the vast number of degrees of freedom while retaining the ability to be locally adjusted to the background.
  - Outperforms both standard local and global algorithms.