Comparison of Structural Models for Target Detection in Hyperspectral Imagery

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ABSTRACT

This work presents a comparison of different methods for structural modeling of hyperspectral imagery for target detection. We study structured models, based on linear subspaces and convex polyhedral cones, and their application for target detection. Different training methods are studied: Singular Value Decomposition (SVD) is used for subspace modeling, Positive Matrix Factorization (PMF) for convex cone, Constrained PMF (cPMF) and Maximum Distance (MaxD) for convex hull. We study different detectors based on orthogonal and oblique projections for subspace and convex polyhedral cones and evaluate their performance. Experimental results using HYDICE imagery are presented.

TARGET DETECTION

Detection using Unstructured Model

\[ \bar{H}_0 : \mathbf{x} = \mathbf{v} \quad \text{Target absent} \]

\[ \bar{H}_1 : \mathbf{x} = \mathbf{t} + \mathbf{v} \quad \text{Target present} \]

Likelihood Ratio Test (LRT) is given by

\[ \Lambda(x) = \frac{p(x \mid \bar{H}_1)}{p(x \mid \bar{H}_0)} > \eta \]

Detection using Structured Model

\[ \bar{H}_0 : \mathbf{x} = \mathbf{B} \mathbf{a} + \mathbf{w} \quad \text{Target absent} \]

\[ \bar{H}_1 : \mathbf{x} = \mathbf{B} \mathbf{t} + \mathbf{a} + \mathbf{w} \quad \text{Target present} \]

Detectors are developed based on orthogonal and oblique projections for subspace and convex polyhedral cones. The Orthogonal Subspace Projector (OSP) is given by. (Chang, 1994):

\[ \mathbf{D}_{OSP}(x) = \mathbf{P}_{\mathbf{B}^\perp} \mathbf{x} = \mathbf{P}_{\mathbf{B}^\perp} \mathbf{X} = \mathbf{P}_{\mathbf{B}^\perp} \mathbf{X} \]

Where:

\[ \mathbf{P}_{\mathbf{B}^\perp} = \mathbf{B} \left( \mathbf{B}^\top \mathbf{B} \right)^{-1} \mathbf{B}^\top \]

It is the projection matrix onto the space spanned by \( \mathbf{B} \). Orthogonal projection onto background subspace.

Based on the properties of the orthogonal subspace projector, we can rewrite the OSP equation:

\[ \mathbf{D}_{OSP}(x) = \mathbf{P}_{\mathbf{B}^\perp} \mathbf{x} = \mathbf{P}_{\mathbf{B}^\perp} \mathbf{X} \]

Detection with threshold = 0.90

**EXPERIMENTAL RESULTS**

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<thead>
<tr>
<th>SVD: Subspace Modeling</th>
<th>PMF: Convex Cone</th>
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<tr>
<td>Histogram of ( \mathbf{D}_{OSP}(x) )</td>
<td>Histogram of ( \mathbf{D}_{OSP}(x) )</td>
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<tr>
<td>Detection with ( \mathbf{k} = 6 )</td>
<td>Detection with ( \mathbf{k} = 6 )</td>
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<tr>
<td>No. detected pixels ( 1105 (43%) )</td>
<td>No. pixels of false alarm ( 1702345 (0.07%) )</td>
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<td>ROC curves for Orthogonal and Oblique Projections</td>
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<th>Detection Probability</th>
<th>False Alarm Probability</th>
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**CONCLUSIONS AND FUTURE WORK**

A study of different methods for structural modeling of hyperspectral imagery for target detection was presented.

- Results show that structured models based on polyhedral cones and convex hulls that take into consideration the positive nature of the data outperform subspace methods for target detection.
- Oblique projections are more computationally expensive.

As future work:

- More cases need to be studied to establish which method and modeling approach gives the best overall performance.
- Study different methods for the estimation of the number of endmembers.

**PUBLICATION**


**STRATEGIC RESEARCH PLAN**

Target detection is an important application of hyperspectral imagery. Better understanding of models and training techniques will allow for improved information extraction (RICE). This is of importance in biomedical, defense and security applications.

**REFERENCES**