The impact of band selection on hyperspectral point target detection algorithms

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ABSTRACT

Hyperspectral imaging (HSI) data contain a continuous sampling of the observed radiation over hundreds of narrow spectral bands. With the increase of the number of spectral channels, spectral redundancy and processing time increase; in addition, the signal to noise ratio per image declines. There is thus a delicate tradeoff in deciding on the proper number of bands to use in any algorithm.

One particular application for spectral data is target detection. This can be done as anomaly detection (when the target signature is not known) and matched target detection when the target is known. Widely used statistical filters for HSI data that enable target detection and anomalies detection are the RX algorithm [1], MF algorithm [1] and ACE algorithm [2].

One formulation of the of **the MF algorithm [1]** is

$$r_{mf} = \left(\vec{t}^T \overrightarrow{\overrightarrow{\Phi}}^{-1}(\vec{x} - \vec{m})\right)^2 = .. = \|t'\|^2 \cdot \|(x-m)'\|^2 \cdot cos^2\theta$$

where t is the target signature, x is the pixel under examination, m is an estimate of the pixel based on the background, and ϕ is the covariance matrix evaluated from the background. The primed variables are obtained by transforming the axes as defined by the inverse covariance matrix. When the target signature is unknown, one can detect anomalies by using **the RX algorithm [2]**,

$$r_{rx} = \left((\vec{x} - \vec{m})^T \vec{\vec{\Phi}}^{-1} (\vec{x} - \vec{m}) \right)^2 = .. = \|(x - m)'\|^2$$

This algorithm replaces the target signature with the residual's own signature, i.e., the best possible choice of a match filter. The angle in such a case is obviously 0.

A third algorithm, **Adaptive Cosine Estimator (ACE)**
[2] is given by

$$r_{ace} = \frac{(\vec{x} - \vec{m})^T \vec{\vec{\Phi}}^{-1} t \left(t^T \vec{\vec{\Phi}}^{-1} t \right) t^T \vec{\vec{\Phi}}^{-1} (\vec{x} - \vec{m})}{(\vec{x} - \vec{m})^T \vec{\vec{\Phi}}^{-1} (\vec{x} - \vec{m})} =..= cos^2\theta$$

Only the angle between the target and the residual signal is used for evaluation; the magnitude of the residual is not needed.

A "good" detector must be sensitive to the target characteristics while rejecting false alarms. There is no a-priori way for us to know which of the three algorithm will be prove to be a better detector of targets. In addition, if I am limited in the number of bands that I can use, it is not obvious 1. which will be the best bands, 2. whether the same bands should be used for all three algorithms and 3. what is the optimum number of bands.

In this paper, we explore the influence of band selection and dimensionality reduction of hyperspectral data on these three point target detection algorithms. We wish to reduce the computational burden and to maximize the algorithms' performance by taking into consideration high spectral correlation. In order to measure the discrimination capability of target detection algorithms, we implement a metric to quantitatively evaluate our algorithm for a particular combination of target signature, spectral cube, and bands chosen. Band selection was done in several ways; we evaluate our results both with exhaustive search and a "sub-optimal" selection algorithm.

Index terms – Hyperspectral imaging (HSI), band selection, point target detection..

References

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