EFFECTS OF ENDMEMBER DIMENSIONALITY ON SUBPIXEL DETECTION PERFORMANCE

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1. INTRODUCTION

Target characterization is an important aspect of any detection algorithm. When detecting subpixel targets in hyperspectral imagery (HSI) however, characterization of the competing background signatures (endmembers) within the pixel is just as important. Unlike conventional full-pixel detection where the pixel contains either target or background signatures, subpixel targets are a combination of the target and the competing background signatures as described by the linear mixing model [1]. While target signatures are usually known, most subpixel detectors must rely on extraction methods to adaptively estimate the background endmembers from the scene.

In this paper, the importance of estimating the correct number of endmembers for subpixel target detection is shown. To demonstrate this hypothesis, various state-of-the-art methods from intrinsic to virtual dimensionality statistics are identified. Additionally, a new method for estimating the number of endmembers is presented based on the subpixel detection algorithm, the desired target signature, and the hyperspectral image being analyzed. A comparison of this new metric to current state-of-the-art methods shows gains in a number of experiments on real-world HSI data. Additionally, the experiments show how important correct estimation of the number of endmembers is to subpixel detection performance.

2. ALGORITHM DESCRIPTION

A significant amount of research has gone into identifying the correct number of endmembers for a scene. Most algorithms have focused on what has been termed “intrinsic” dimensionality [2]. These dimensionality measures such as the Akaike Information Criterion (AIC) [3], the Minimum Description Length (MDL) [4], and the Empirical Indicator Function (EIF) [5] focus on identifying the unique spectral signatures in an image. While these metrics are well suited for classification purposes, they may not be the best measure for subpixel detection applications.

In target detection, the background must be characterized such that the probability of detecting the target is maximized while the probability of detecting a false alarm is minimized. In such cases, the number of endmembers required to characterize the background may be significantly more than the intrinsic dimensionality. The reasons are varied, but can be quickly summarized as the additional endmembers may be signatures due to shadowing effects, sensor artifacts, and finer material identification (e.g. coarse sand vs. fine sand). This has been noted in [2] where the best number of endmembers varied for different applications. This measure of dimensionality relative to detection performance has been termed virtual dimensionality [2] and includes a number of metrics by researchers such as Chang and Du [2] and Thai and Healey [6].

Unfortunately, most of the currently developed methods do not account for either the detector or the target signature. This oversight can lead to significantly degraded detection performance over what is possible. Thai and Healey [6] have one of the few algorithms that takes these parameters into consideration. Based on their approach, we propose the following metric based on a synthetic mixed pixel such that

\[
\hat{m} = \max_{m} \mathcal{S}(x, E, S)
\]
where $S \in \mathbb{R}^{L \times P}$ are the $P$ known target spectral signatures of dimension $L$, $E_m \in \mathbb{R}^{L \times m}$ is an endmember matrix containing $m$ endmember column vectors, and $x$ is a synthetically mixed pixel based on the target signature $S$ and the image background pixels. Thus, this new method simultaneously takes into account the detector, the target signature, and the hyperspectral image which should lead to improved subpixel detection performance. Additionally, the new method can be extended to any structured subpixel detector and endmember extraction algorithm.

3. EXPERIMENTAL RESULTS

The detector used for these experiments is the Adaptive Matched Subspace Detector (AMSD) algorithm [1]. This is a standard subpixel detector in the literature that uses the eigenvectors of the image correlation matrix as the background endmembers. This type of detector allows us to apply all of the endmember dimensionality estimates on similar background information (image covariance or image correlation matrix). The experiments are performed across multiple images and target types. In all cases, the new metric shows an improvement in determining the number of endmembers for subpixel detection applications. Additionally, the results show how significantly the number of endmembers impact subpixel detection performance when all other variables are kept constant.

REFERENCES


