

# Applications of Angle-Based Band Selection for Efficient Hyperspectral Processing

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## 1 Optimizing Angle-Based Metrics

Hyperspectral data consists of hundreds of contiguous spectral bands collected for each pixel in a scene. The spectral measurements convey the material properties of objects within a pixel, and provide the foundation for applications that exploit differences in spectral values.

In previous work, we focused on the most commonly used distance metric for comparing two hyperspectral signals,  $\mathbf{x}$  and  $\mathbf{y}$ , known as the Spectral Angle Mapper (SAM):

$$\theta(\mathbf{x}, \mathbf{y}) = \arccos\left(\frac{\langle \mathbf{x}, \mathbf{y} \rangle}{\|\mathbf{x}\| \|\mathbf{y}\|}\right), \quad 0 \leq \theta \leq \frac{\pi}{2}. \quad (1)$$

It was demonstrated that the angle measured by SAM for two spectra can be increased by carefully selecting a subset of bands from the total set collected by the sensor. This capability results in the ability to increase the amount of contrast between target signatures, such that those bands may make the classification of an unknown pixel into one class or another easier, since there is more contrast to exploit. Experiments show that the number of bands that yield the largest angle is often only a fraction of the total available bands.

The current efforts extend this formulation with a new band selection technique that is based on an analytical decomposition of SAM. It selects bands to increase the angular separation between two classes of pixels,  $\mathbf{X}$  and  $\mathbf{Y}$ , where each class is populated by a small number of reference pixels,  $\mathbf{X} = \{\mathbf{x}_1, \dots, \mathbf{x}_M\}$ ,  $\mathbf{Y} = \{\mathbf{y}_1, \dots, \mathbf{y}_N\}$ . This model is identical to the scenario in material identification where a relatively small number of measurements (not enough to accurately estimate a covariance) with a spectroradiometer provide the basis for a template signature for a certain material. An unknown pixel is compared to numerous template spectra, most commonly with SAM, and assigned to the class having the smallest distance. The ability to select bands that yield greater angular contrast results in better classification performance. Results will be demonstrated

## 2 Architectural Gains

The idea of maximizing the angular contrast between two classes of spectra results in a hierarchical architecture for performing material identification that yields better classification performance (due to the increase in contrast) and faster real-time processing (due to the reduction in the number of bands). Moreover, the results of angle-tests that compare an unknown spectrum to template spectra using specific bands can be utilized to effectively rule out other classes without performing a numerical calculation. This is due to the properties possessed by a valid distance metric. The benefits of such gains will be discussed in this paper.

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