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IMAGINE Subpixel Classifier™ vs. Linear Spectral Unmixing

White Paper

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IMAGINE Subpixel Classifier™ vs. Linear Spectral Unmixing

This Technical White Paper describes key performance differences between IMAGINE Subpixel Classifier and commercial alternatives based upon linear spectral unmixing (aka Linear Mixing Model or LMM) and typically sold as subpixel analysis modules. IMAGINE Subpixel Classifier is part of IMAGINE Professional suite of classification tools.

Differences in Approach

A linear spectral unmixing classifier characterizes the scene being processed by a carefully selected set of n representative scene materials, where n is less than or equal to the number of spectral bands in the sensor. Each image pixel is assumed to be some mixture of these n component materials. The user is asked to select and create training sets for the n component materials. The process then reports the fraction of each component material in each pixel. The output takes the form of a set of n fraction planes, with each fraction plane reporting the amount (fraction) of one of the component materials in each pixel.

In contrast, IMAGINE Subpixel Classifier characterizes the scene being processed by the amount (fraction) of one specific material, rather than n materials, in each image pixel. The user is asked to create a training set for only one specific material of interest, not for n scene-characteristic materials. The process performs a search for that specific material in each pixel, and it reports the amount of material it finds. The output takes the form of a single fraction plane for the material of interest, rather than n fraction planes for n characteristic scene materials. If the user wishes to classify more than one material, the process is repeated for each material.

Usable Imagery

The linear spectral unmixing approach has been found to have utility only for image data with five or more spectral bands. This is because each pixel is modeled as some combination of n scene materials, and n cannot exceed the number of sensor bands. One of these materials is typically set aside for “shade,” requiring that the scene be represented by only n - 1 representative materials.

Except for the most uniform of scenes, such as desert and snow-covered scenes, fewer than four materials is generally an inadequate representation. Among the common multispectral sensors, Landsat Thematic Mapper imagery can be effectively used, but SPOT, the Indian IRS sensor, and Landsat Multispectral Scanner imagery generally cannot be used. Hyperspectral sensor imagery can be used, but it has been found that the practical upper limit to n is 6 - 8, even though this is well below the theoretical number of materials that could be used with hyperspectral image data.

IMAGINE Subpixel Classifier can be used with any of the common multispectral and hyperspectral sensors. The number of spectral bands affects the minimum amount of material that can be detected in a pixel, but the process can be used effectively with sensors having three or more spectral bands.

Accuracy

IMAGINE Subpixel Classifier typically has significantly higher classification performance accuracy than the linear spectral unmixing classifier. IMAGINE Subpixel Classifier is not restricted to modeling each pixel with a small-restricted set of six or fewer scene-characteristic materials.

Up to 45 candidate materials, including the material of interest, are considered for each pixel. The list of candidate materials is different for each pixel, being tailored to the specific spectral characteristics and context of each pixel. Each pixel is modeled as combinations of the material of interest and one of the other 44 candidate materials, which are referred to as background materials. These candidate backgrounds are typically not pure materials, but rather represent the 44 most likely composites of materials mixed with the material of interest in the pixel.

The materials included in the background lists can vary widely from pixel to pixel. This allows for a much more tailored and accurate representation of the spectral properties of each pixel than when each pixel is required to be composed of the same six or fewer materials. The result is much higher level of fraction accuracy with the IMAGINE Subpixel Classifier.

Discrimination Sensitivity

IMAGINE Subpixel Classifier is more versatile with respect to the materials that can be discriminated and classified. The scene-representative materials used in the linear spectral unmixing approach are constrained to be as spectrally different from each other as possible. A typical set of materials might include a representative vegetation class, soil class, a bright cultural material such as concrete, and a dark cultural material such as tarmac, water and shade. There is very little flexibility in the choice of material. A set cannot include two vegetation classes, or two soil classes, or two classes of water, for example, because they would be too spectrally similar.

As a result the linear spectral unmixing approach cannot, for example, be reliably used to discriminate one type of vegetation from another. It can only provide an estimate of how much vegetation may be in a pixel. In contrast, IMAGINE Subpixel Classifier is ideally suited for making fine discriminations between similar materials, such as discriminating different vegetative species from each other, different cultural materials from each other, different soil or water classes from each other, etc., with minimal confusion.

The discrimination sensitivity represents the most fundamental difference between these two processes. The linear spectral unmixing approach provides a method of classifying broad categories of materials, while the IMAGINE Subpixel Classifier is for classifying specific materials that may be spectrally very similar (or very different) from other materials in the scene.

Ease of Use

Another fundamental difference between IMAGINE Subpixel Classifier and the linear spectral unmixing classifiers is in ease of use. IMAGINE Subpixel Classifier was designed from the outset to be highly automated and easy to use. Its level of difficulty is comparable to that of a traditional nonparametric supervised classifier, such as the minimum distance classifier.

When working with IMAGINE Subpixel Classifier, the user is asked to develop a training set and signature for a single material of interest. There is no need to develop training sets or signatures for any other scene materials. The background materials required by the process are all identified and handled automatically without user involvement. The user is additionally asked to identify cloud-free portions of the scene, which the process uses to automatically perform atmospheric corrections. Once the signature and atmospheric correction factors are developed, classification is automatic. There are some differences in ease of use, depending on the signature derivation option selected, but in all cases the process is relatively easy to use.

In contrast, the linear spectral unmixing classifiers are relatively complex and manual processes, they requiring significant user skill and interaction. These classifiers are often considered to be advanced research tools. The user is asked to first identify the n scene characteristic materials. These materials not only need to be representative of the scene as a whole, but also they need to be as spectrally different from one another as possible. Ideally, they should be “spectrally orthogonal” to one another, and frequently the user must use advanced tools to find these materials.

After the materials are identified, the user needs to develop training sets for each of the materials, and then develop spectral signatures for each. For certain applications the user may need to develop signatures from spectral libraries, using relatively complex procedures to convert the laboratory or field spectra into sensor-compatible and atmospherically-compatible data formats.

Signature Portability

IMAGINE Subpixel Classifier includes an automatic atmospheric correction feature. This allows signatures for materials of interest to be used not only in the scene from which the signature was developed, but also in other scenes having different dates and geographical locations. For many applications, adequate training sets for materials of interest cannot always be developed from a scene being processed. With IMAGINE Subpixel Classifier, signatures can be developed using training sets from other scenes (where training sets are available) and they can be directly applied to the scene of interest.

This kind of automatic scene-to-scene portability of signatures is not available from the commercial competition. Atmospheric corrections can be developed from available packages, but the corrections are generally inadequate to allow for automatic signature portability. Signatures need to be derived using training sets from the scenes being processed, which can significantly limit the utility of the linear spectral unmixing classifiers.

The signature portability feature of the IMAGINE Subpixel Classifier opens a new possibility of developing signature libraries that can be made available to users. This can allow for routine monitoring, change detection, and other uses with high market potential.