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IMAGINE Subpixel Classifier™

White Paper

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IMAGINE Subpixel Classifier™

Overview

Supervised Spectral Classifier

IMAGINE Subpixel Classifier is a state-of-the-art, non-parametric, supervised spectral classifier that performs subpixel spectral analysis by detecting and reporting whole and subpixel occurrences of a specific Material of Interest (MOI) in multispectral imagery.

IMAGINE Subpixel Classifier successfully identifies a specific material when materials other than the target are present in a pixel. It discriminates between spectrally similar materials, such as individual plant species, specific water types, or distinctive building materials.

IMAGINE Subpixel Classifier uses a scene-derived environmental correction process that enables you to develop a reference signature in one scene and then apply that signature to other scenes from different dates and geographic locations. And, as a fully integrated, add-on application module to ERDAS IMAGINE®, it works in conjunction with wide range of Geographic Imaging software solutions and is found within IMAGINE Professional within the ERDAS IMAGINE software suite.

Benefits

IMAGINE Subpixel Classifier allows you to…

- Classify objects smaller than the spatial resolution of the sensor.
- Identify specific materials within mixed pixels.
- Detect materials that occupy from 100% to as little as 20% of a pixel.
- Report the fraction of material present in each pixel classified.
- Develop signatures that are portable from one scene to another.
- Normalize imagery for atmospheric effects.
- Search wide-area images quickly to detect small or large features mixed with other materials.

Problem Solving with IMAGINE Subpixel Classifier

Urban Ecosystem Analysis

American Forests wanted to document the value of tree-covered landscapes within urban areas such as the Puget Sound metropolitan area. They also wished to provide urban decision-makers with information and tools to measure the value of natural landscapes and to incorporate more trees into future development. The study base data was Landsat images from 1972, 1986 and 1996. The pixel resolution of the Landsat Thematic Mapper (TM) data from 1986 and 1996 was 30 meters. The Landsat Multispectral Scanner (MSS) image available for 1972 was 80-meter resolution. To add to the challenge, tree cover varied not only within each scene but also over time from one year's image to the next. Ground survey over the area was impractical and cost prohibitive, especially retroactively. And at any point in the study years, significant tree cover throughout the area was fragmented and occupied less than whole image pixels.

American Forests found their solution in IMAGINE Subpixel Classifier. It allowed them to divide each pixel into one of nine vegetation categories, eight of them measuring vegetation presence and one measuring development. American Forests then processed the results using their CITYgreen software. An ArcView for Windows application, it combines GIS analytic capabilities with scientific and engineering information to put a dollar value on the contributions trees make to the urban environment.

Crop Detection

A seed producer was looking for a method to more accurately assess acreage of a specific crop. They wished to monitor the crop's cultivation in different regions of the world to improve their forecast of raw material supply.

Distinguishing the target crop from other spectrally similar vegetation is difficult. It is often planted in remote areas dispersed over large tracts of land and is interspersed with other crops and vegetation. On the-ground survey is nearly impossible. High-resolution, airborne imagery is prohibitively expensive.IMAGINE Subpixel Classifier was used to develop two spectral signatures of the target crop - leaf-oriented and stem-oriented - from a satellite image containing known locations of the crop. The original image was used to validate and calibrate the two signatures, and to successfully detect all known fields with no false alarms.

Taking advantage of IMAGINE Subpixel Classifier's Environmental Correction function, the two signatures derived from the original scene were applied to other scenes that were captured on multiple dates. IMAGINE Subpixel Classifier successfully detected the crop of interest in scenes of Texas, Kansas, Mexico, and Brazil.

Fuel Spill Detection

The U.S. Air Force wanted to determine if there had been fuel spills in remote areas of a decommissioned air base, to plan its conversion to civilian use. Access to the area was limited. Historical records had not been kept. The budget was tight and results were needed quickly.

Utilizing a Landsat TM scene of the base, IMAGINE Subpixel Classifier was used to generate a signature from two known spill sites. The training pixels, which were estimated to contain approximately 25 percent contaminated soil, were used to derive a signature of residual hydrocarbon material from the spill.

IMAGINE Subpixel Classifier was able to detect seven potential spill sites. Using the results to cue themselves, investigators confirmed the accessible locations by on-site inspection - on the tarmac, on the runway, in the soil, and at a marine repair facility.

Wetland Verification

Researchers from Clemson University wanted to identify wetlands in rural forested areas of South Carolina and Georgia under pressure from development. If they could map the wetlands, development plans could be modified at an early stage to avoid the strictly regulated wetland areas.

They knew that Tupelo and Cypress are wetland indicator species in the region. The two species had not been successfully classified using traditional classifiers since pixels were mixed with forest debris, grasses, and ground features visible through the tree crowns. On-the-ground survey methods were prohibitively expensive and time consuming. High resolution photography was not viable due to the large scale required to identify individual tree species. And the complex forest environments made species identification using satellite imagery almost impossible. IMAGINE Subpixel Classifier solved the problem by identifying Tupelo and Cypress in this forest environment, allowing quick and accurate mapping of wetland areas. A detailed field verification study demonstrated detection accuracy near 90% for both species. Further, IMAGINE Subpixel Classifier's unique Environmental Correction feature allowed signatures used in processing the original scene to be successfully applied to other scenes in South Carolina and Georgia.

Waterway Mapping

In the Tingo Maria area of Peru, waterways serve as a key element in the area's transportation and communication network. Hundreds of miles of uncharted waterways exist in this inaccessible region. The area is too vast and mountainous for airborne imagery to be collected and effectively used for mapping.

IMAGINE Subpixel Classifier identified hundreds of miles of small rivers and streams using signatures derived from a large river in the area. Multiple training signatures were required to develop signatures for a range of depths and water quality conditions. Other spatial filtering and interpolation techniques were applied to the results to compensate for an abundance of overhanging growth partially obstructing the waterways. The end product was a comprehensive waterway map for the region generated using Landsat TM imagery.

Forest Management

In South Carolina, the USDA Forest Service manages a region where various species of southern yellow pine had been planted in discrete, well-defined stands. Over time, aggressive species like loblolly pine had infiltrated many of the non-loblolly stands.

The Forest Service was uncertain of the extent of loblolly pine infiltration. Ground survey was impractical. They used IMAGINE Subpixel Classifier to determine the extent of loblolly pine infiltration. Automatic background identification and removal enabled the discriminations of loblolly pine from longleaf and slash pines. Detections of the intrusive loblolly were tallied within designated stands in the Forest Service GIS to quantify the amount of loblolly pine in each stand.

IMAGINE Subpixel Classifier Approach

IMAGINE Subpixel Classifier produces a non-parametric signature for a specific material, identifies all pixels in an image as either containing the material or not, and classifies all pixels that do contain the material into classes based on how much of the material they contain.

To start, IMAGINE Subpixel Classifier automatically identifies a set of background materials present in the image. An environmental correction process derives a set of atmospheric correction factors which can be used to normalize the image data and minimize environmental factors when applying signatures in multiple scenes. A supervised signature derivation process derives a signature for a specific MOI from the subpixel component that is common to the training set pixels. The derived signature is then used to classify the image. The classification process subtracts candidate background spectra and determines the best subpixel residual fit and reports the corresponding fraction. A signature tolerance factor can be used control the spectral filtering process.

Material Pixel Fraction

IMAGINE Subpixel Classifier groups the pixels it identifies as containing the MOI into Material Pixel Fraction (MPF) classes based on the spatial fraction of the pixel that the MOI occupies. Each class contains pixels with similar, subpixel amounts of the MOI. For example, if you specify eight MPF classes, each class contains a 10% MPF range down to the minimum detectable value of 20%. Class eight would contain all the pixels that have 90 to 100% of the pixel area occupied by the MOI, class seven 80 to 89%, etc.

Unlike traditional parametric classifiers, which sort image pixels into different spectral classes that can be interpreted as multiple land cover classes, IMAGINE Subpixel Classifier identifies pixels containing a single MOI. To classify more than one material, you run it separately for each material.

Scene-to-Scene Signature Transfer

IMAGINE Subpixel Classifier's Environmental Correction function compensates for image-unique acquisitionconditions such as time of year, sun angle, and level of atmospheric haze. By enabling you to compensate for scene environmental factors prior to Signature Derivation, the Environmental Correction function allows you to develop a "cleaner" reference signature for your specific material.

Before you apply your reference signature to another scene, you utilize Environmental Correction to compensate for atmospheric and environmental conditions that are unique to the date and time of its acquisition. By applying the scene-derived environmental correction factors, IMAGINE Subpixel Classifier enables you to develop a reference signature in one scene that you can apply to other scenes from different dates and geographic locations.

IMAGINE Subpixel Classifier Data Input

IMAGINE Subpixel Classifier can be used with any 8-bit or 16-bit multispectral data source. It requires at least 3 bands of multispectral data. It works with 3-band and 4-band SPOT multispectral images and 6 of the 7 Landsat Thematic Mapper spectral bands. The sixth (thermal) Landsat TM band is ignored for all processing.

Multispectral imaging is frequently available in several formats. While IMAGINE Subpixel Classifier can be used with any available format, certain formats provide distinct advantages with respect to the quality of derived signatures and the discrimination performance of classifications. Factors such as the resampling technique, pixel size,

and geometric correction level can have an effect on the performance of IMAGINE Subpixel Classifier.

Preferred Resampling Technique

The nearest neighbor resampling technique provides consistently superior signature quality and discrimination performance. Nearest neighbor resampling most closely preserves the spectral integrity of the image pixels. Cubic convolution and bilinear interpolation resampling perform spectral averaging of neighboring pixels, yielding pixels with spectral properties that are less likely to provide optimal results.

Optimum Data Pixel Size

The optimum data pixel size is the same as the nominal ground sampling distance for the sensor. Landsat TM data, for example, is available in 30-, 28.5-, and 25-meter pixel size formats. The sensor's ground sampling distance is 30-meters. To produce the smaller pixel sizes, pixels are artificially duplicated and inserted into the scene. These extra pixels can degrade spectral quality and ultimately affect signature quality and discrimination performance. Therefore, the 30-meter format is recommended for Landsat TM imagery.

Geometrically Uncorrected Data

Geometrically uncorrected data generally produces superior signature quality and classification performance. Both SPOT MS XS and Landsat TM data are available in geometrically uncorrected and geometrically corrected formats. Geometric correction in Landsat TM data introduces duplicate line artifacts (DLAs) and can produce significant band-to-band misregistration, significantly degrading the spectral integrity of image pixels. For Landsat TM data, the highest spectral integrity option is the radiometrically corrected, geometrically-uncorrected format. For SPOT imagery, Level 1A processing provides the highest spectral integrity.

IMAGINE Subpixel Classifier Process

IMAGINE Subpixel Classifier consists of one optional and four required processing functions. Quality Assurance is optional. When appropriate, you would normally run it first. Preprocessing, Environmental Correction, Signature Derivation, and MOI Classification are required functions. Each plays an important role in the development and application of subpixel signature derivation and classification. You must run each in the order described.

Data Quality Assurance

IMAGINE Subpixel Classifier provides an optional automatic artifact removal process that identifies and removes data artifacts commonly found in Landsat and other imagery. This process improves the reliability of the results and saves manual labor. A utility is also provided to check images for the occurrence of Duplicate Line Artifacts (DLAs). These sometimes occur when a row of recorded satellite information is duplicated during resampling by the data supplier to fill gaps in data. Depending on their frequency and location, DLAs may compromise the integrity of the image or the classification results.

Preprocessing

Preprocessing is the first required process. It automatically surveys the image to generate candidate backgrounds which are compared to image pixel in the scene. These candidate backgrounds are used during Signature Derivation and MOI Classification to generate a residual for each pixel that is a candidate MOI spectrum. There are no results to view from Preprocessing.

Environmental Correction

Environmental Correction prepares imagery for Signature Derivation and MOI Classification. It automatically calculates a set of factors to compensate for variations in atmospheric and environmental conditions during image acquisition. The final output is a file containing environmental correction factors that are applied to an image during Signature Derivation and MOI Classification.

By compensating for atmospheric and environmental variations, signatures developed using IMAGINE Subpixel Classifier may be applied to scenes of differing dates and geographic regions, making the signature scene-to-scene transferable. Environmental correction is also needed for in-scene situations, since the energy detected by the sensor is not the same as the energy actually reflected from the MOI due to atmospheric scattering, absorption by water vapor, and other atmospheric distortions.

Signature Derivation

The Signature Derivation function allows you to develop an IMAGINE Subpixel Classifier signature for a particular MOI. The signature contains not only the material reflectance spectrum but also additional information required for subpixel classification and scene-to-scene use.

You derive a signature using a training set defined by an IMAGINE Area of Interest (AOI) tool; or by a classification derived using a traditional IMAGINE classification tool, together with the source image, an environmental correction file, and the MPF in the training set.

You can develop an IMAGINE Subpixel Classifier signature using either a whole-pixel or subpixel training set. The Signature Derivation process extracts the subpixel part of the material signature that is common to all pixels in the training set. The resulting signature is equivalent to a whole pixel signature of that common material. Therefore, regardless of the training set you use, the signature you develop can classify the MOI at either wholepixel or subpixel levels.

MOI Classification

The last step in the IMAGINE Subpixel Classifier process is MOI Classification. The function applies a spectral signature to an image to locate pixels containing the MOI. Inputs include the image, preprocessing output file, environmental correction file, signature file, and a signature tolerance number to control the number of false detections.

Output from MOI Classification is an overlay image that contains the detected locations of the MOI. The classification output may be displayed using an IMAGINE Viewer. The total number of pixels detected and the MPF for each pixel classified are reported in the IMAGINE Raster Attribute Editor histogram.

IMAGINE Subpixel Classifier and Traditional Classifiers

Complement to Traditional Classifiers

The primary difference between IMAGINE Subpixel Classifier and traditional classifiers is the way in which it derives a signature from the training set and then applies it during classification. Traditional classifiers typically form a signature by combining the spectra of all training set pixels for a given feature. The resulting signature contains the contributions of all materials present in the training set pixels. In contrast, IMAGINE Subpixel Classifier derives a signature for the component that is common to the training set pixels, the MOI. The IMAGINE Subpixel Classifier signature is therefore “purer” for a specific material and can more accurately detect the MOI.

IMAGINE Subpixel Classifier and traditional classifiers perform best under different conditions. IMAGINE Subpixel Classifier may work better to discriminate among species of vegetation, distinctive building materials, or specific types of rock or soil. Traditional classifiers may be preferred when the MOI is composed of a spectrally varied range of materials that must be included as a single classification unit. For example, a forest that contains a large number of spectrally distinct materials and spans multiple pixels in size may be classified better using a minimum distance classifier. IMAGINE Subpixel Classifier can complement a traditional classifier by identifying subpixel occurrences of specific species of vegetation within that forest.

IMAGINE Subpixel Classifier and Linear Spectral Unmixing

Different Approaches

A linear spectral unmixing classifier characterizes a scene with a carefully selected set of n representative scene materials. n must be less than or equal to the number of spectral bands in the sensor. A further requirement is that these n scene materials should be orthogonal (equally different from each other). 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, each fraction plane reporting the amount (fraction) of one of the component materials in each pixel.

IMAGINE Subpixel Classifier, in contrast, characterizes the scene being processed by the amount (fraction) of one specific material, rather than n materials, in each image pixel. It models each pixel as a linear combination of only two components, the MOI and a background. The MOI is assumed to be in every pixel, while the background component is assumed to be different from pixel to pixel. When using

the IMAGINE Subpixel Classifier, the user selects training pixels used to provide the spectrum (signature) for the MOI and not for n scene-characteristic materials. The background spectra (64 candidate backgrounds) are derived autonomously by the process. Unlike linear spectral unmixing, there is no requirement for spectral orthogonality, i.e., the background can be spectrally similar to the MOI. This generally allows IMAGINE Subpixel Classifier to provide finer levels of discrimination then linear unmixing approaches.

The subpixel process performs a search for that specific material in each pixel, and it reports the amount of material it finds. The output is a single fraction plane for the MOI, rather than n fraction planes for n characteristic scene materials. If the user wishes to classify more than one material, the user repeats the process for each material.

Data Types

Any multispectral or hyperspectral data source, including airborne and satellite, with three or more spatially registered bands can be used with IMAGINE Subpixel Classifier, such as

- Landsat TM
  - Nearest-neighbor resampling
  - 30m pixel size
  - Spacecraft orientation
- SPOT XS and SPOT XI (multispectral) Level 1A
- IKONOS
- DigitalGlobe Quickbird
- OrbImage Orbview 3

Summary

IMAGINE Subpixel Classifier addresses the mixed pixel problem. You can identify a single material even when other materials are present in the pixel. And you can discriminate between spectrally similar materials such as individual plant species, specific water types, or distinctive building materials.

By enabling you to normalize scene environmental factors prior to signature derivation, and because it uses only common elements of training set pixels in deriving a signature, IMAGINE Subpixel Classifier allows you to develop “cleaner” reference signatures for a specific material than alternate methods.

Because of IMAGINE Subpixel Classifier’s automatic scene-specific environmental correction feature, which does not require you to use external models, you can develop spectral signatures that are scene-to-scene transferable. You can apply a signature developed in one scene to another scene acquired at a different place and time by the same sensor.

IMAGINE Subpixel Classifier derives a signature for a specific material, identifies all pixels in an image as either containing the material or not, and classifies all pixels that do contain the material into classes based on how much of the material they contain. When used to best advantage, IMAGINE Subpixel Classifier discriminates materials better than other methods.