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Object Analyst Module: Description

Object Analyst is an add-on module to CATALYST Professional Essentials.

Object Analyst provides tools for segmentation, classification, and feature extraction. Object Analyst includes an all-in-one interface within CATALYST Professional's Focus application that is designed to guide you through segmenting your imagery, extracting features, creating training sites, classification (including creating custom rules for classification), reforming shapes, and performing an accuracy assessment.

Researchers have more recently considered that a pixel is not a true geographical object, and it is not the optimal spatial unit for mapping a landscape. Moreover, the traditional pixel-based image-analysis algorithms showed their inability to cope with high-resolution imagery; that is, imagery with resolution typically finer than 5 meters per pixel. These factors have contributed to the shifting of the model to the wider use of object-based image analysis (OBIA).

OBIA does not analyze a single pixel, but rather a homogeneous group of pixels — image objects. An object, contrary to a pixel, provides richer information, including spectrum, texture, shape, spatial relationships, and ancillary spatial data. In turn, spatial context can be exploited to emulate a human analyst, who intuitively identifies various objects in an image, rather than individual pixels, by considering various properties, such as size, texture, shape, and the spatial arrangements of these objects to understand the semantics.

The fundamental objective of OBIA, therefore, is to use segmentation to reduce complexity of image data, and to use the extracted image objects and their corresponding attributes (features) to develop strategies for thematic classification. With OBIA, images are segmented to make image objects from various groups of pixels to represent meaningful objects in the

scene. Ontologically, this provides more accurate and reliable identification and extraction of real-world features and at more appropriate scales. Moreover, it provides the opportunity to divide map data into homogenous objects of various spatial scales.

CATALYST is a PCI Geomatics Enterprises Inc. brand, which has been introduced to put our leading-edge technology into the hands of decision makers. CATALYST provides proven algorithms rooted in photogrammetry and remote sensing to offer engineers, environmental management, and geospatial professionals access to leading edge and scalable software solutions and platforms.

Table of Contents

Module Prerequisites

Object Analyst is an add-on module to CATALYST Professional Essentials bundle or is included in the following bundles: Satellite bundle, Aerial bundle, SAR bundle, Complete bundle, Developer bundle.

Workflow

A simple process flow for object-based image analysis (OBIA) is shown in Figure 1. After preprocessing, a typical OBIA analysis starts with segmenting an image into primitive objects. You then further group the objects together into classes of interest by exploiting their spectral properties, shape measures, context, and so forth.

Figure 1: Workflow of object-based classification

The preprocessing steps involve operations such as orthorectification, radiometric enhancement, removing shadow, detecting outliers, or creating a new layer(s) such as vegetation indices, texture channels and so forth, so that the data is suitable for image segmentation and feature extraction before classification.

Image segmentation is the first step in OBIA. The objective is to partition an image into statistically homogenous regions or objects (segments) that are more uniform within themselves and differ from their adjacent neighbors.
Each segment is characterized by a variety of attributes (features), including spectral properties (band statistics of a segment), shape, texture, context, and so forth. The segments, however, do not have the thematic information at this stage and need classification to assign class (group) membership to each.

Object Analyst in CATALYST Professional's Focus Application

Object Analyst can be accessed through the **Analysis** menu. The interface includes a Process Canvas, which guides users through process steps that can be run separately or once properly defined, automatically.
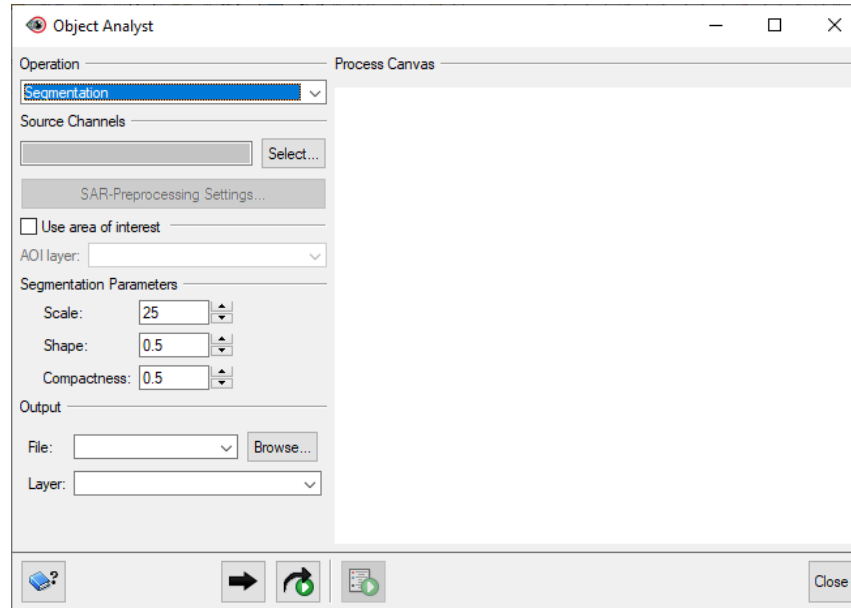
1

Figure 2: Object Analyst's Process Canvas interface

The process steps are listed here and described below:
- Segmentation
- Attribute Calculation
- Training Site Editing
- Classification
- Rule-based Classification
- Post-classification Editing
- Accuracy Assessment
- Batch Classification

Segmentation

Segmentation is the process of extracting discrete regions of image objects. This is achieved by stratification of an image. These image-objects are used further as the basic unit of analysis for developing image-analysis strategies, including classification and change detection.

The underlying segmentation algorithm in Object Analyst is a hierarchical step-wise region grown by using random "seeds" spread over the entire image. This method can be classified as a "bottom-up" optimization routine that starts with a pixel and ends with segments that are groups of like pixels. The criteria that define the growth of a region can be based on the difference between the pixel intensity and the mean of the region. The algorithm assesses the local homogeneity based on the spectral and spatial characteristics. The size of the object

2

is controlled with the value for scale, which you specify. The larger the scale, the larger the output object. Other homogeneity criteria are based on shape and compactness.

The result of the segmentation process is as follows:

- An initial abstraction of the original data
- Creation of a vector (polygon) representation of the image objects

The results of segmentation can be exported as a vector data set and viewed in third-party software.

Constraining segmentation to an area of interest

If necessary, you can constrain segmentation to a specific area of interest (AOI). You do so by selecting a vector file in PCIDSK format that you have created containing only polygons of the AOI you want.

Attribute Calculation

In Object Analyst an attribute represents some information about an image object. Various characteristics of image objects are referred to as attributes of a segment.

You can compute the following types of attributes:

1. Statistical - Statistical attributes are computed based on the image pixels under an object (polygon). Attributes are computed for each of the selected image bands and added to the attribute table of the vector segment layer as new fields. The following attributes can be collected:
    - Minimum value of the pixels beneath an object in a selected band
    - Maximum value of the pixels beneath an object in a selected band
    - Mean value of the pixels beneath an object in a selected band
    - Standard deviation value of the pixels beneath an object in a selected band

2. Geometric attributes - Geometric attributes are computed by analyzing the polygon boundary created during segmentation, so raster information is not required. Object Analyst computes many commonly used shape descriptors such as:
    - Compactness - A measure to indicate how closely packed a shape is. A circle is the most compact.

      Compactness = Sqrt(4 * As / pi) / O, where As is the area of the object, and O is the perimeter of the object (outer contour).

    - Elongation - The ratio of the height and width of a rotated minimal bounding box. In other words, rotate a rectangle so that it is the smallest rectangle in which the object fits, and then compare its height to its width.

      Elongation = Major Axis Length / Minor Axis Length

o Circularity - The circularity ratio represents how like the object's shape is to a circle. Circularity is the ratio of the area of a shape to the perimeter of the shape's square.

$C = A_s/O^2$, where A_s is the area of the shape, and O^2 is square of the shape's perimeter.

o Rectangularity - How rectangular a shape is; that is, how much it fills its minimum bounding rectangle.

$R = A_s/A_R$, Where A_s is the area of a shape, and A_R is the area of the minimum bounding rectangle.

o Convexity - The relative amount that an object differs from a convex object. Convexity is calculated by forming the ratio of the perimeter of the convex hull of an object to the perimeter of the object itself.

Convexity = convex-hull perimeter ÷ object perimeter

o Solidity - The density of an object. Solidity is calculated as the ratio of the area of an object to the area of a convex hull of the object. A value of 1 indicates a solid object, and a value less than 1 indicates an object having an irregular boundary or containing holes.

Solidity = area ÷ convex-hull area

o Form Factor - The measure that compares the area of a polygon to the square of the perimeter. The form-factor value of a circle is 1, and the value of a square is pi ÷ 4.

Form factor = 4 ⁄ pi ⁄ area ÷ sqrt (perimeter)

o Major-axis length - The length of the major axis of an oriented bounding box enclosing the polygon.

Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.

o Minor-axis length The length of the minor axis of an oriented bounding box enclosing the polygon.

Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.

3. Vegetation Indices attributes - You can select from several Vegetation Indices (VI) to perform quantitative and qualitative evaluations of vegetation cover, vigor, growth dynamics, and more.

The following table provides descriptions of each Vegetation Index that can be calculated:

Attribute	Short name	Description
Green/Red Vegetation Index	GRVI	`GRVI = (Green - Red) ÷ (Green + Red)`
Greenness Index	GI	`GI = ((2.0 × Green) - (Red + Blue)) ÷ ((2.0 × Green) + Red + Blue)`
Vegetation Difference Index	VDI	`VDI = NIR - Red`
Ratio Vegetation Index	RVI	`RVI = NIR ÷ Red`
Normalized Difference Vegetation	NDVI	`NDVI = (NIR - Red) ÷ (NIR + Red)`
Transformed Difference Vegetation Index	TDVI	`TDVI = (NIR - Red) ÷ (NIR + Red) + .5`
Soil Adjusted Vegetation Index	SAVI	`SAVI = ((NIR - Red) ÷ (NIR + Red + L)) × (1 + L)` The `L`-value is based on the amount of green vegetative cover. `L` is a default of 0.5, which means, generally, areas of moderate green vegetative cover.
Modified Soil Adjusted Vegetation Index	MSAVI2	`MSAVI2 = (0.5) × (2(NIR + 1) - √((2 × NIR + 1) - 8(NIR - Red)))`
Global Environmental Monitoring Index	GEMI	`GEMI = eta × (1 - 0.25 × eta) - ((Red - 0.125) ÷ (1 - Red))` Where `eta = (2 × (NIR - Red) + 1.5 × NIR + 0.5 × Red) ÷ (NIR + Red + 0.5)`
Leaf Area Index	LAI	`LAI = (3.618 × EVI) - 0.118` Where `EVI (Enhanced Vegetation Index) = 2.5 × (NIR - Red) ÷ (1 + NIR + (6 × Red) - (7.5 × Blue)`

4. Texture attributes: Texture measures can be calculated for a specific direction or directional invariant for all pixels in an input image. The measures are based on second-order statistics calculated from the gray-level co-occurrence matrices.

Attribute	Description	Algorithm
Mean	Cooccurrence mean	`Mean_i = SUM(i,j=0,N-1)(i*P(i,j))` Average gray-level in the local window.

Standard deviation	Cooccurrence standard deviation	`Var_i = SUM(i,j=0,N-1)(P(i,j)*(i - Mean_i)**2)`
		 `Std. Deviation_i = SQRT(Var_i)`
		
		 Gray-level standard deviation in the local window. High when there is a large gray-level standard deviation in the local region.

Entropy	Cooccurrence entropy	`SUM(i,j=0,N-1)(-P(i,j) * LOGe(P(i,j))),` `assuming that 0 * LOGe(0) = 0.` Entropy is high when the elements of GLCM have relatively equal values. It is low when the elements are close to either 0 or 1 (that is, when the image is uniform in the window).
Angular second moment	Cooccurrence angular second moment	`SUM(i,j=0,N-1)(P(i,j)**2)` This is the opposite of Entropy. It is high when the GLCM has few entries of large magnitude, low when all entries are almost equal. This is a measure of local homogeneity.
Contrast	Cooccurrence contrast	`SUM(i,j=0,N-1)(P(i,j)*(i-j)**2)` Contrast is the opposite of Homogeneity. It is a measure of the amount of local variation in the image. It is high when the local region has a high contrast in the scale of SPATIAL.

Training Site Editing

Before you can perform a classification or an accuracy assessment, you must have ground-truth data. In remote sensing, ground truth refers to information collected on location. With ground-truth data, image data can be related to real features and materials on the ground. By collecting ground-truth data, remote-sensing data can be calibrated, which aids in the interpretation and analysis of what is being sensed.

With supervised classification, the ground-truth data acts as a training set, which is used by the learning algorithm to generate a classification model.

In Object Analyst, you collect training samples for both the supervised classification and accuracy assessment in the same window. Primarily, you will use on-screen interpretation in the viewer and select segments of various classes.

Classification

Classification is systematic grouping of objects into sets or classes based on their similarities. The goal in Object Analyst is to group extracted image objects or segments into appropriate classes that a human analyst can identify intuitively.

This is achieved through object-based classification. Classification of a segment can be achieved either by labeling a segment as a selected class and assigning a color to it, or by adopting more advanced more advanced computational procedures.

With Object Analyst, you can perform either of two types of classification:
1. Supervised - Supervised classification is a process to find a model, or function, by analyzing the features of a data set of which the class memberships are known. This function is then used to predict the class memberships for target population.

   Essentially, supervised classification is a two-step approach.
   o The first step is to build a learning model to describe predetermined classes for a data set. The construction of the learning model is based on the analysis of data items or concepts for which class memberships are predetermined or known: data items known collectively as training samples.

   o In the second step, the learned model is applied to new (target) data items to predict their class membership. The supervisory component of this procedure is in the training phase, which provides the classifier with a way to assess a dependency measure between features (attributes) and classes.

   Users can select between Support Vector Machine (SVM) or Random Trees (Random Forest) algorithms for supervised classification.

   Support Vector Machine (SVM) is a machine-learning methodology that is used for supervised classification of high-dimensional data. With SVM, the objective is to find the optimal separating hyperplane (decision surface, boundaries) by maximizing the margin between classes, which is achieved by analyzing the training samples located at the edge of the potential class.

   Random Trees (Random Forest) is an ensemble learning method that has been implemented for image classification. It operates by constructing a multitude of decision trees during training and outputs the class selected by most trees.

2. Unsupervised - Object Analyst provides unsupervised classification based on the k-means clustering algorithm. Clustering algorithms search for generic data patterns among the feature [variable] spaces. No target variable is identified, as such. Clustering algorithms search for patterns among all the input features related to objects and group them into relatively homogeneous clusters.

The goal of clustering is normally descriptive and to discover new categories. Therefore, this strategy learns from observation rather than examples, and hence does not require a prior hypothesis or training set. The core objective is finding the natural boundaries in feature space for the number of clusters you specify.

Rule-based Classification

With Rule-based Classification, you can define a custom classification rule based on a specific property (feature), or properties, of a segment. You can define a rule to either assign a class to segments that meet the requirements of the rule or remove the segments from the class.

Object Analyst provides two methodologies for creating these rules or conditions:

1. Object Analyst Condition Builder window

   In this window users can define a condition for rule-based classification. The condition can be based on up to two features (attributes). That is, you can construct a maximum of two conditions per rule. Both conditions can be based on a single attribute, or on two different attributes linked by a logical AND or OR operator.
   For example, one could specify a two-part condition where i) classification occurs on an area attribute with a value of greater than 100800 and ii) less than 109800 for the same area attribute.

2. An alternative to creating a condition in the Object Analyst Condition Builder window is to use feature visualization. In the Feature Visualization window, you can dynamically select the vector objects (polygon segments) or update the existing selection in the vector layer based on a given feature (field) and its value range (filter).

   You select the field you want, and then define the range. The polygon segments in that range are then selected in the viewer. Changing the range value reapplies the filter and updates the selection set. You can immediately see the effects of the selected filter, and experiment to select the one most suitable.

Post-classification Editing

As a post-classification step, users may need to merge two or more polygons or spilt one or more polygons. You can do so by using either of two methods:

- Reforming shapes by using automatic dissolve

  Automatic dissolve, merges two adjacent polygons based on class membership; that is, segments belonging to the same class and that are adjacent to each other are dissolved to create a bigger object. The internal boundaries of such segments are removed. The output will exclude all the attribute fields, except the field that contains the class-membership information. It is this field that is used to dissolve the segments.

- Reforming shapes by using interactive edits

  An alternative to reforming shapes with Automatic dissolve is to use Interactive edits. To do so, you must select a layer that contains one or more polygons with class

8

information. Object Analyst provides you with some basic tools to select and edit the polygon data.

- Adding, modifying, and removing classes:

   You can add, modify, and remove classes, as necessary. You can also assign objects to a class, and change the style of how classes are displayed in the view pane.

Accuracy Assessment

You can evaluate the overall accuracy of a supervised classification by running Accuracy Assessment. This operation compares a reference field, generated by an analyst using training sites editing tool, and a classification field, generated by running a classification.

The reference field and the classification field must be of the same segmentation file. When a segmentation file contains several reference and classification fields, it is a good practice to compare a classification with the reference field used to create it.

This process generates an assessment report that includes:
- Sample Listing – Report includes all assessed samples, described with georeferenced position, image coordinates, classified value/name, and reference value/name are displayed.
- Error (Confusion) Matrix – Matrix of all classes between reference data and classified data is displayed.
- Accuracy Statistics – Various accuracy statistics, such as overall accuracy, kappa coefficient, and their confidence intervals are displayed.

Batch Classification

By running a batch classification, you can run classification simultaneously on a group or collection of images with similar qualities of acquisition. The collection can be any aerial, satellite, or SAR imagery you want to classify similarly, such as, but not limited to the following:
- Airphotos (strips or individual images)
- Stack of historical imagery
- Overlapping images
- Contiguous images

You first run classification on an individual image that you want to use as reference for the batch you want to process. After you are satisfied with the results, you can run a batch classification on several images to apply the same classification to each. The batch classification applies a segmentation step, an attribute-calculation step, a classification step (using Support Vector Machine or Random Forest, (based on the training-model file you create from the first individual image you classified), and any number of rule-based classification steps.

Object Analyst for Synthetic Aperture Radar (SAR) Data

In Object Analyst, the workflow of working with synthetic-aperture radar (SAR) data differs from that of other types of remote-sensing (RS) data.

Object Analyst supports SAR data ingested to a PCIDSK file or directly in its raw vendor format.

SAR imagery comes in many formats and processing levels identifiable by the matrix type in the image metadata. The matrix type determines which, if any, SAR preprocessing parameters you can apply, and which SAR attributes you can calculate, as shown in the following table.

Matrix type	Channel type**	Segmentation, preprocessing	Predefined attributes
[c1r] Single polarization, detected	1 x [16U] (uncalibrated) - or - 1 x [32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[c1c] Single polarization, complex	1 x [C16S] (uncalibrated) - or - 1 x [C32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[c2r] Dual polarization, detected	2 x [16U] (uncalibrated) - or - 2 x [32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[s2c] Dual polarization, complex*	2 x [C16S] (uncalibrated) - or - 2 x [C32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[s4c] Fully polarimetric, complex	4 x [C16S] (uncalibrated) - or - 4 x [C32R] (calibrated)	• Filtering • Tail trimming • Extra segmentation layers: - L1 (λ1) - L2 (λ2) - L3 (λ3)	• Statistical • Geometrical • Polarimetric

* Compact-polarimetric data is a special case of [s2c] data.
** Calibrated data is recommended for use with Object Analyst.

Segmentation

Object Analyst also includes segmentation tools specifically designed to work with SAR imagery. Once a SAR image is selected as input, you can pre-process the layer (recommended before segmentation). This pre-processing includes:

- Select the type and size of filter you want to use. You can select from either of the following types of filter:
  - Enhanced Lee

- o   Boxcar

- Select whether to apply tail trimming and, if so, the percentage thereof

  To minimize the effect of backscattering, you can apply tail trimming. With SAR data, frequency histograms are often characterized by strong outliers in the rightmost tail of the data distribution; that is, point targets with a high-backscattering coefficient several magnitudes higher than the bulk of the data. Segmentation is influenced strongly by these "scatterers" and can produce substandard results over distributed targets, such as forest and water.

Attribute Calculation

Specific SAR attribute calculations are included as options. These specific tools are designed to leverages SAR-specific analysis of texture, scattering mechanisms, and more.

1. Polarimetric attributes - The predefined polarimetric attributes are available for fully polarimetric images only (matrix type = [s4c]). The attributes correspond to a selection of parameters, from various polarimetric decompositions, that have the potential to discriminate among a diverse set of land-cover classes.

   - o   Scattering type
   - o   Entropy
   - o   Anisotropy
   - o   Orientation angle
   - o   First eigenvalue Lambda1
   - o   Second eigenvalue Lambda2
   - o   Third eigenvalue Lambda3
   - o   Double-bounce scattering
   - o   Volume scattering
   - o   Surface scattering
   - o   HH-VV phase difference
   - o   Maximum degree of polarization
   - o   Minimum degree of polarization
   - o   Maximum of received power
   - o   Minimum of received power
   - o   Maximum of scattered intensity

Object Analyst Functions

The following functions can be executed either independently or sequentially via an EASI™ or Python™ script.

- OACALCATT – Calculate object attributes
- OACALCATTSAR – Calculate object attributes for SAR imagery
- OAFLDNMEXP - Export names of attribute fields from vector segment to a text file
- OAGTIMPORT - Import ground-truth points into an existing segmentation
- OASEG – Segment an image
- OASEGSAR – Segment a SAR image
- OASVMCLASS – Object-based SVM classifier
- OASVMTRAIN – Object-based SVM training
- OARTCLASS – Object-based Random Trees (Forest) classifier
- OARTTRAIN – Object-based Random Trees (Forest) training