FEATURE ANALYST V5.0

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ABSTRACT

Feature Analyst has become the tool of choice for analysts worldwide who want to collect features from remotely-sensed imagery. Feature Analyst fits within popular workflows, as it exists as an extension to RemoteView®, ELT®, ArcGIS®, ERDAS IMAGINE® and GeoMedia®. This paper provides a summary of the current, new, and future functionality of Feature Analyst, in particular the new functionality that will be available in the next release (version 5.0). The new version includes new and improved 2-D and 3-D techniques for collecting roads, buildings, land-cover, small objects, and other features. It also has new techniques for updating features in existing sets of imagery, change detection, fused sets of imagery, clean-up tools and auto-attribution tools. In particular, this paper presents four new capabilities: tighter integration of Feature Analyst with LIDAR Analyst, an assisted building extraction tool, an assisted road extraction tool, and new conflation capabilities designed to update existing databases with information from new images.

INTRODUCTION

High-resolution satellite imaging of the earth and its environment represents an important new technology for the creation and maintenance of geographic information systems (GIS) databases. Geographic features such as road networks, building footprints, vegetation, etc. form the backbone of GIS mapping services for military intelligence, telecommunications, agriculture, land-use planning, and many other vertical market applications. Keeping geographic features current and up-to-date, however, represents a major bottleneck in the exploitation of high-resolution satellite imagery. The Feature Analyst software provides users with a powerful tool for extracting object-specific geographic features from high-resolution panchromatic and multi-spectral imagery. The result is a tremendous cost savings in labor and a new workflow process for maintaining the temporal currency of geographic data. The Feature Analyst approach to object-recognition provided a paradigm shift to the feature collection industry by providing intelligent computer agents that automatically model the feature-recognition process. The user gives the system (computer program) a sample of extracted features from the image. The system then automatically develops a model that correlates known data (such as spectral or spatial signatures) with targeted outputs (i.e., the features or objects of interest). The resulting learned model classifies and extracts the remaining targets or objects in the image. The release of Version 5.0 provides many significant enhancements and offers even more solutions to analysts. The paper first gives a brief overview of the existing Feature Analyst system, before concentrating on four significant enhancements.

BACKGROUND: EXISTING FEATURE ANALYST CAPABILITIES

In 2001 Visual Learning Systems, Inc. (now Overwatch Systems) developed Feature Analyst as a commercial-off-the shelf (COTS) feature extraction extension for ArcGIS in response to a the geospatial market's need for automating the production of geospatial features from earth imagery. Feature Analyst evolved to work as an extension to all prominent GIS and Image Processing applications, as it is available as an extension to RemoteView®, ELT®, ArcGIS®, ERDAS IMAGINE® and GeoMedia®. Feature Analyst has become the dominant

Automated Feature Extraction (AFE) system on the market due to the fact that it provides: (a) a simple interface and workflow process, (b) the ability to take into account spatial context (contextual classification), (c) the ability to mitigate clutter, (d) the ability to learn disjunctive concepts, and (e) the ability to incorporate ancillary data sources such as elevation models. Feature Analyst works by having an analyst provide sample target features in an image set, then it learns from these examples and automatically detects the remaining features in the image set.

When classifying the contents of imagery, there are only a few attributes accessible to human interpreters. For any single set of imagery these are: Shape, Size, Color, Texture, Pattern, Shadow, and Association. Traditional image processing techniques incorporate only color (spectral signature) and perhaps texture or pattern into an involved expert workflow process; Feature Analyst incorporates all these attributes, behind the scenes, with its Learning Agents. Figures 1, 2, and 3 show the value of using these visual attributes, such as spatial association, in feature extraction. Figure 1 is the sample image. In this case, we want to extract white lines on airport runways. Using only spectral information, the best an analyst can do is shown in Figure 2; all materials with similar reflectance are extracted. Figure 3 shows the Feature Analyst using a "square 7x7" input window. In this case, one needs to know the neighboring pixels are pavement or grass when extracting lines. This example illustrates the need to take into account spatial information when conducting true feature extraction.

Figure 1. Original image of an airport with the task of extracting lines on the runway.

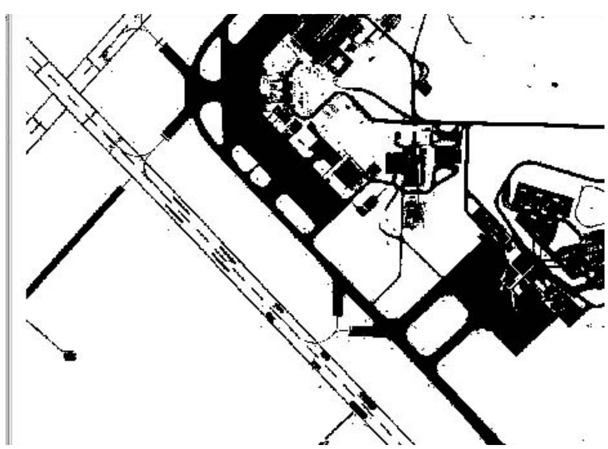

Figure 2. The best results possible with extracting using only spectral information with no spatial context.

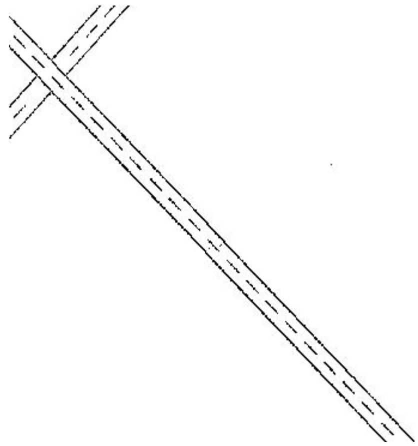

Figure 3. Feature Analyst classification using both spatial association and spectral properties.

Feature Analyst utilizes the natural ability of humans to recognize objects in complex scenes and does not require the user to *explain* the human-visual process in an algorithmic form. Since the system does not require programming knowledge, users with little computational experience can effectively create AFE models for the tasks under consideration. In addition to automating the extraction of single features, Feature Analyst offers many tools for easily creating multi-class extractions. For instance, an analyst can segment an image into numerous classes, for example, water, low-vegetation, high-vegetation, and buildings. Additional capabilities of Feature Analyst include change detection, 3D feature extraction, data fusion, unsupervised classification, and advanced clean-up and post-processing tools (such as convert to line).

NEW FEATURE 1: COMBINING FEATURE ANALYST WITH LIDAR ANALYST

. Automated feature extraction has been the long-term goal of geospatial data production workflows for over 30 years. The largest hurdle has been creating AFE workflows that are effective across many degrees of freedom found in imagery and features (e.g., change of season or different terrain types). The challenge, therefore, is developing a flexible approach for transferring domain knowledge of a feature extraction model from image to image that is capable of adapting to changing conditions (e.g., image resolution, pixel radiometric values, landscape seasonal changes, and the complexity of feature representation). In 2006, Feature Analyst came out with the concept of Feature Modeler and the Feature Model Library as tools within Feature Analyst to better automate the feature extraction workflow process while allowing it to adapt to changing conditions. Feature Modeler provides users with a comprehensive set of tools for examining and refining feature models created with Feature Analyst (see Figure 4). Feature models, designated as AFE models, include the parameter settings for a classifier to extract a particular feature including spatial context, and hierarchical learning passes. Benefits of this approach include the following:

- Analyst can create, edit and refine the inner workings of an AFE model including the pixels used for classification of a feature with spatial processing, priority of input bands, rule extraction from a complex learned model and the parameter settings for a learning algorithm.
- Technicians can access AFE models and run them in an interactive mode or run the model in a silent batch mode. In interactive mode the technician doesn't need to worry about creating the proper workflow or setting parameters for the learning algorithm; rather they only have to provide a labeled set of examples. In batch mode the process is completely automated where a single AFE model, or multiple AFE models, can be run against a single image or a directory of images,

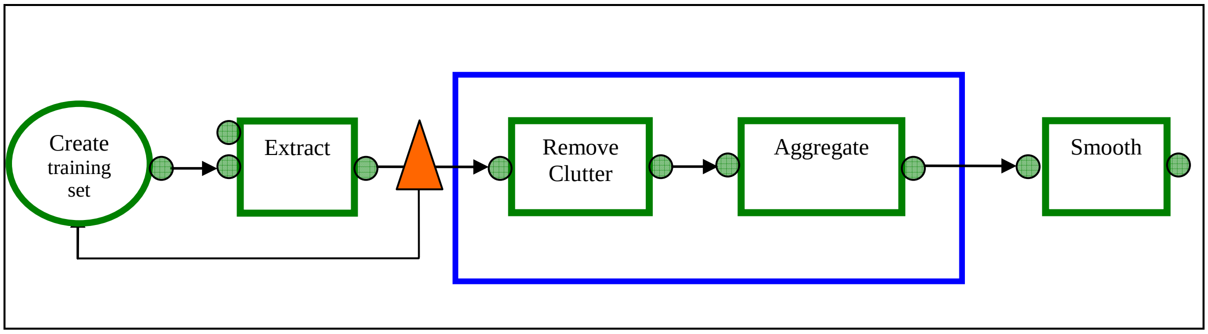

Figure 4. A simple AFE model representation showing the five steps used in processing. Each of the processing steps can be adjusted by a user and the model can be re-used for a different image.

The Feature Model Library resides within a relational database and is used for storing AFE models to support enterprise-wide geospatial processing. Analysts can search and retrieve AFE models for subsequent processing in a batch mode to extract features from imagery without any training sets. The Feature Modeler software allows a user to import an AFE model to examine and adjust parameter settings or deploy a learning model in a batch-processing mode.

Soon, Feature Modeler will be available in LIDAR Analyst. LIDAR Analyst, released in 2005, provides a highly automated solution for the extraction of bare earth, 3D buildings and trees from airborne LIDAR. The software addressed traditional bottlenecks in collecting features from LIDAR, editing complex 3-D geometries (i.e. rooftops), and attributing features. The automated feature extraction techniques for LIDAR Analyst require minimal human intervention and are highly-valued because the resulting output is both spatially accurate and automatically attributed. The new release of Feature Analyst will tightly combine the workflows of Feature Analyst and LIDAR Analyst to create a synergistic system that is more accurate than either one separately

NEW FEATURE 2: ASSISTED BUILDING EXTRACTION

The new release of Feature Analyst will introduce a new approach for collecting buildings from mono and stereo imagery. The Feature Analyst Building Collection Toolkit is a collection of semi-automated tools that are designed to minimize the amount of user input that is required to extract a complete building from mono and stereo imagery. In the case of stereo, the tools will automatically create a 3D model of the building using our image correlation algorithms. In addition, the tools automatically extract certain attributes and allow users to specify additional attributes for each building. Therefore analysts can extract production quality 3D buildings in a much shorter amount of time.

The traditional workflow for collecting buildings consists of the user hand digitizing each building by placing a vertex on each building corner. Recent advances in AFE software, such as Feature Analyst, provide an automated way to collect buildings. However, in dense urban areas AFE tools can produce mixed results since the variation of the buildings in the scene is so great that it becomes a difficult concept to learn and thus produces a significant amount of clutter. A more robust approach is the use of intelligent interactive tools that are designed to extract a specific feature such as buildings. The approach leverages the advances made with AFE software and significantly reduces the number of mouse clicks that it takes to digitize buildings. The advantages of using the Feature Analyst Building Collection Toolkit instead of hand digitizing are:

- *Improved buildings outline extraction.* For simple rectangular buildings users can click-and-drag an oriented rectangle around the outline of the building, which reduces the number of mouse click from 4 to 1. For complex buildings, the user can click-and-drag an oriented rectangle around the building extent and have the extraction tool automatically figure out the building rooftop outline, which can significantly reduce the number of mouse clicks depending on the complexity of the building.
- *Auto-attribution and assisted attribution.* When creating a building polygon feature layer, the user has the option of adding auto-attribution fields (building area, length, and orientation) and custom attribution fields (building type, building function, etc.). This allows the users to collect and attribute buildings in a single pass and create production quality buildings in a shorter amount of time.

- *Simplified tool set.* The typical building collection process can require the use of multiple tools that perform a specific task. Constantly switching between tools increase the number of mouse clicks, thus increasing collection time. The Building Collection Toolkit uses multi-function tools and keyboard hot keys to quickly switch between tools or collection modes. In fact, all of the functionality of the building collection toolkit is contained within a single tool, which equates to increased productivity and less time wasted switching between tools.

When collecting buildings from stereo images, the Building Collection Toolkit has the following additional advantages to those outlined above:

- *Lower implementation costs.* The traditional method for collecting buildings from stereo requires users to have a high end graphics card and specialized stereo viewing equipment, which can cost thousands of dollars. The Building Collection Toolkit does not require any specialized hardware. Users collect 3D buildings by viewing each mono image in a split-screen view.
- *Reduced user fatigue.* Viewing images using stereoscopic glasses can cause eye strain, thus significantly increasing user fatigue. Since the Building Collection Toolkit does not require any specialized stereoscopic glasses, users experience less fatigue and thus become more productive.
- *Improved building height detection.* When collecting 3D buildings from stereo, the buildings height above ground is computed using an image correlation algorithm where the rooftops are matched between the left and the right image.
- *Easy to use height adjustment tools.* Users can select to adjust the height of the rooftop or the base of the building then simply push a key on the keyboard to increase or decrease the height.
- *Detection of multi-component buildings.* The Building Collection Toolkit will automatically recognize when the user is digitizing a building component so that the base of the component will be adjusted to match the elevation of the main building's rooftop.
- *Incorporate elevation data into the collection process.* Rather than constantly having to adjust the ground elevation for the current extraction area, the user now has the option of specifying a ground elevation model, such as a DTM, DTED, or elevation raster. When available, this model is used to automatically set the ground elevation of the current building extraction area.

Figures 5 and 6 shows the steps to collecting a building from a mono image using the Building Collection Toolkit. In this example, to collect the building by hand would require a total of 15 mouse clicks (one on each building corner). Using the Building Collection Toolkit, the user only needs to make one mouse click and a drag operation. From this simple example it is easy to see the time savings the Building Collection Toolkit can provide.

Figure 5. The user drags a rectangle that encompasses the building **.**

Figure 6. The tool automatically extracts the true building edges.

Figures 7-14 show the steps to collecting a complex building from a stereo pair of images using the Building Collection Toolkit. In this example, to collect the building by hand would require a total of 31 mouse clicks (one on each building corner). In addition, the must take the time to adjust the cursor elevation so that accurate Z values can be captured. Using the Building Collection Toolkit, the user only needs to make 14 mouse clicks and drag operations. Since the Building Collection Toolkit automatically computes the building height, there is no need for the user to adjust the cursor elevation as they collect the building. Again, the time savings is very apparent when using the Building Collection Toolkit.

Figure 7. The building after the initial rectangle.

Figure 8. The building after added rectangle.

Figure 9. The building after added rectangle.

Figure 10. The building after added rectangle.

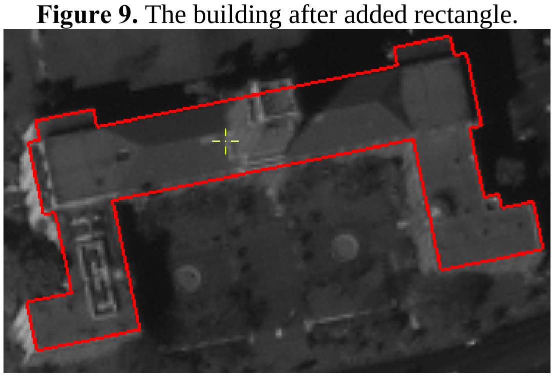

Figure 11. The building after initial rectangles.

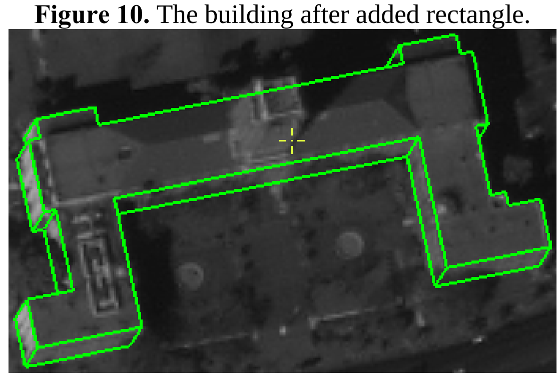

Figure 12. The building after the height is estimated and accepted.

Figure 13. The building after the component roof outline has been defined.

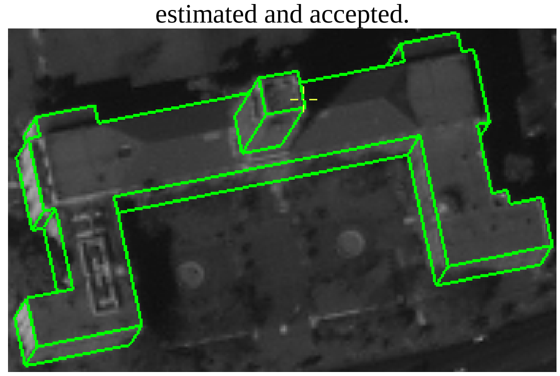

Figure 14. The finished building.

NEW FEATURE 3: CONFLATION AND DATABASE UPDATING

Since GIS began, there has been a requirement for conflation. In the beginning it was copying descriptive geographic information from paper maps into spatial databases. Today the requirement includes copying rich attributes from older data-sets into newer data-sets that more precisely model geographic features. Tools such as Feature Analyst have made it easy and fast to extract highly accurate geographic features from high resolution satellite imagery. These extracted features model the geographic features to sub meter accuracy. However there is often existing databases that, while out of date or slightly inaccurate, contain a wealth of attribute information. For example, a database of buildings for a city may be 8 years old and have missing buildings or inaccurate footprints, but the database may also have a wealth of information attached to each building (e.g., address, property tax, or home owner). Therefore, there needs to be a way of merging the old information in the database with the new information found in a recent image. Feature Analyst will address this need with the release of a set of tools that can perform the following sets of operations:

1. **Vector-to-raster conflation** which provides the ability to align features (lines or polygons) to a high resolution satellite image.
2. **Vector-to-vector conflation** which provides the ability to match vectors (lines or polygons) from two separate data-sets. The vectors can be lines or polygons.
3. **Database update** which provides the ability to define the attributes that will be copied to a final data-set so that it has the best geometries and is richly attributed.

Vector-to-Raster Conflation

The vector-to-raster conflation process provides a tool and a workflow that allows the user to use an existing vector data-set (source layer) and a higher resolution image (target layer) and get back a vector data-set that more accurately is aligned with the features in the image. Vector-to-raster conflation is currently a semi-automated process and involves the work-flow found in Figure 15.

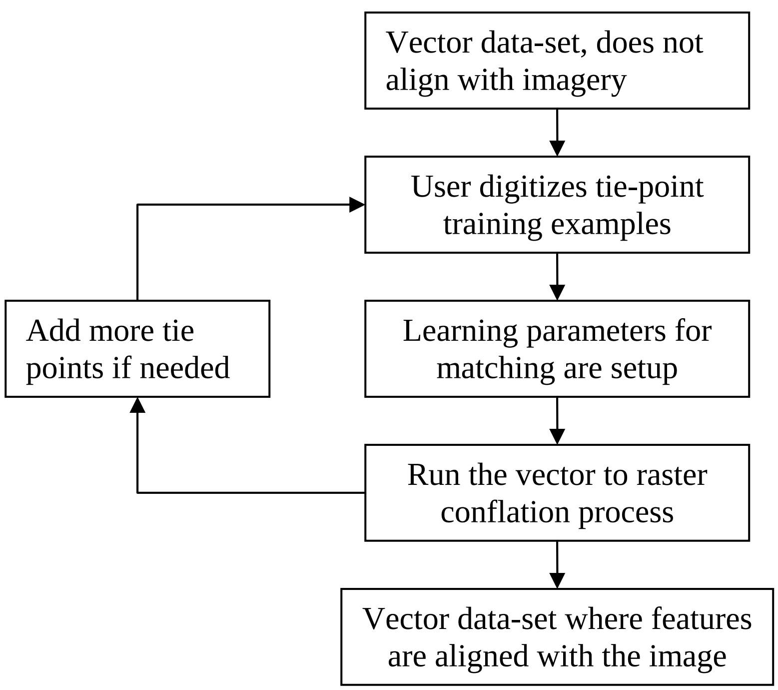

Figure 15. Vector-to-raster conflation.

The user digitizes a few tie-points that are used by the Feature Analyst learner as training examples. The learner uses these tie points to extract features from the image, which are then used to automatically determine more tie points. Tie points are extracted by matching the source layer's features with those extracted by the Feature Analyst learner. Once the tie points have been created, the user starts the vector-to-raster conflation process. The user can specify how the source layer's features and tie points are used to perform the extraction from the image. The user also has the ability to specify parameters that setup the learner. This provides the user maximum flexibility in trying to make the learner pick the best features of interest.

Vector-to-Vector Conflation

The Feature Analyst vector-to-vector conflation tool allows the ability to reliably and accurately copy attributes from one vector layer to another. This is typically required when valuable attributes reside in a layer created from a older or lower resolution image, and better geometry and accuracy exists in a new vector layer created from newer or higher resolution image. The vector-to-vector matching process is used to match features from the source layer (typically the source of attributes) and the target layer (the source for accurate geometries, but can also provide attributes). The vector-to-vector matching process outputs a match layer that contains shapes that were matched between the source and target layers. The match layer contains information about the matches as well as automatically generated tie-points than can be used to transform shapes from the source layer to better align with the target layer. The strength of this process is derived from its iterative nature. Depending on the feature type (lines vs. polygons) matches are made based either on topology or geometric attributes. The algorithm provides for a diverse set of parameters that allow the user to define if the matching will be based upon shape-invariant attributes such as moments, or geometry-specific attributes such as area, perimeter, etc. This is useful in circumstances where the source features are not just displaced but also contain rotation, skew and scale distortion. After having created a first iteration set of tie points, the source features are transformed to more closely match the target layer. At this point another matching process is run yielding a larger number of matches and tie points. The inter-activeness of the algorithm allows the matching process to dynamically find the best matches even if there are large distortions between the two data-sets.

The Update Database Process

The matched layer is output so that the user has a chance to optimize the match results. This can be done by either manually transforming the source layer so that it more closely matches the target layer or by fine-tuning the matching parameters. In addition the user can delete those matches from the match layer that he thinks are not valid. The update database process allows the user to specify how to copy attributes and features from the source and target layers to a final conflated layer. The dialog of this process allows the user to specify not just which features and attributes to copy when there are valid matches, but also which features and attributes to copy when there were no matches found. This gives the GIS analyst greater control over the features and attributes that end up in the final conflated layer. Finally this process allows the user to specify the default values for the fields being created that don't have a source.

NEW FEATURE 4: ROAD TRACKER FOR FEATURE ANALYST

RoadTracker™ is a proprietary application built by GeoEye for collecting production quality road centerlines from multispectral, panchromatic, and radar imagery. RoadTracker exists as an extension to Feature Analyst with the new release of the software. In addition to collecting both paved and unpaved roads, RoadTracker can be used to extract other linear features including trails, paths, narrow rivers, and drainage (see Interactive RoadTracker™ for Feature Analyst – User's Guide). RoadTracker is a departure from the traditional workflow where a user would hand digitize each vertex comprising a road and manually specify various attributes. This is an interactive tool that allows users to specify a few seed points along a particular road and the algorithms behind RoadTracker automatically handles the centerline creation, attribution (including road width, length, and surface type), intersection insertion and topology cleaning. Figures 17 and 18 illustrate an example of how RoadTracker can automatically extract a road centerline from a commercial panchromatic satellite image. It is readily apparent in this example of the potential time savings this particular tool can offer simply by examining the number of mouse clicks it would take to collect the same road by hand.

Figure 17. The user digitizes the start and end point of a road segment.

Figure 18. RoadTracker automatically finds the road between the start and end point.

In cases where the RoadTracker produces an unacceptable result, GeoEye has included various automatic vector editing functions. The automatic vector editing capabilities are invoked each time a new road is collected and include: adjustable node snapping and line snapping tolerances, automatic topology cleaning, automatic installation of corner points, and automatic deep smoothing of lines. The Smart Vector Editing plug-in is designed to quickly fix incorrect road centerlines with single mouse clicks and include the following tools:

- *1-Point Detour.* reroutes a line so that it passes smoothly through a user-specified point.
- *N-Point Detour.* reroutes a line so that it passes smoothly through two or more user-specified points.
- *Move Terminals.* moves one or more road end points to a user-specified location.
- *Straighten.* produces the straightest possible line between the start and end points.
- *Smooth.* removes any waves in a line segment.
- *Fuse.* merges multiple road segments into a single line.