



VISUAL LEARNING
SYSTEMS

Using Feature Analyst™ to Perform Object-Specific Change Detection

A Visual Learning Systems, Inc. White Paper
April 2004

Visual Learning Systems, Inc.

We put the information in GISsm

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INTRODUCTION

Current change detection techniques fall woefully short of meeting government and commercial needs in the GIS industry. Automated change detection methods currently available to the GIS and image analysis community, such as Image Differencing, Image Ratioing, and Image Regression, led to the development of a change mask and do not provide adequate change information for target specific objects. Categorical change extraction techniques, such as Change Vector Analysis, Post-Classification Comparison, and Direct Multi-date Classification, are expensive, depend on the accuracy of scene classification, require expert computer programming, and most importantly, do not produce an adequate level of accuracy to be useful for most domains. The Feature Analyst Professional provides the first viable automated change detection system, allowing users to quickly update their GIS data layers to reflect the changes over time. As the cost of high-resolution imagery decreases the need to update geospatial data becomes more pressing to support accurate and timely decisions.



The Feature Analyst can work with time series satellite and aerial panchromatic, color composite, multi-band, and radar imagery...



...and can perform object-specific change detection fast and accurately.

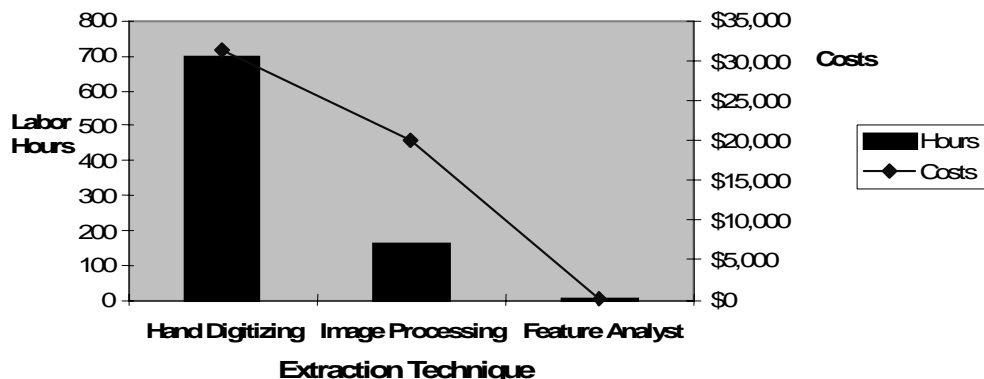
ABOUT VISUAL LEARNING SYSTEMS AND FEATURE ANALYST

Visual Learning Systems, Inc. (VLS) is a machine learning research and software development company creating 21st century information technology tools for the geographic information systems (GIS) industry. The flagship product of VLS is Feature Analyst. With research funded through NIMA (now the NGA) of the Department of Defense as well as NASA, VLS built Feature Analyst into the premiere feature extraction tool on the market. Along with software, VLS provides custom feature extraction work, as well as professional training, both at VLS Headquarters in Missoula, Montana, and on site with clients.

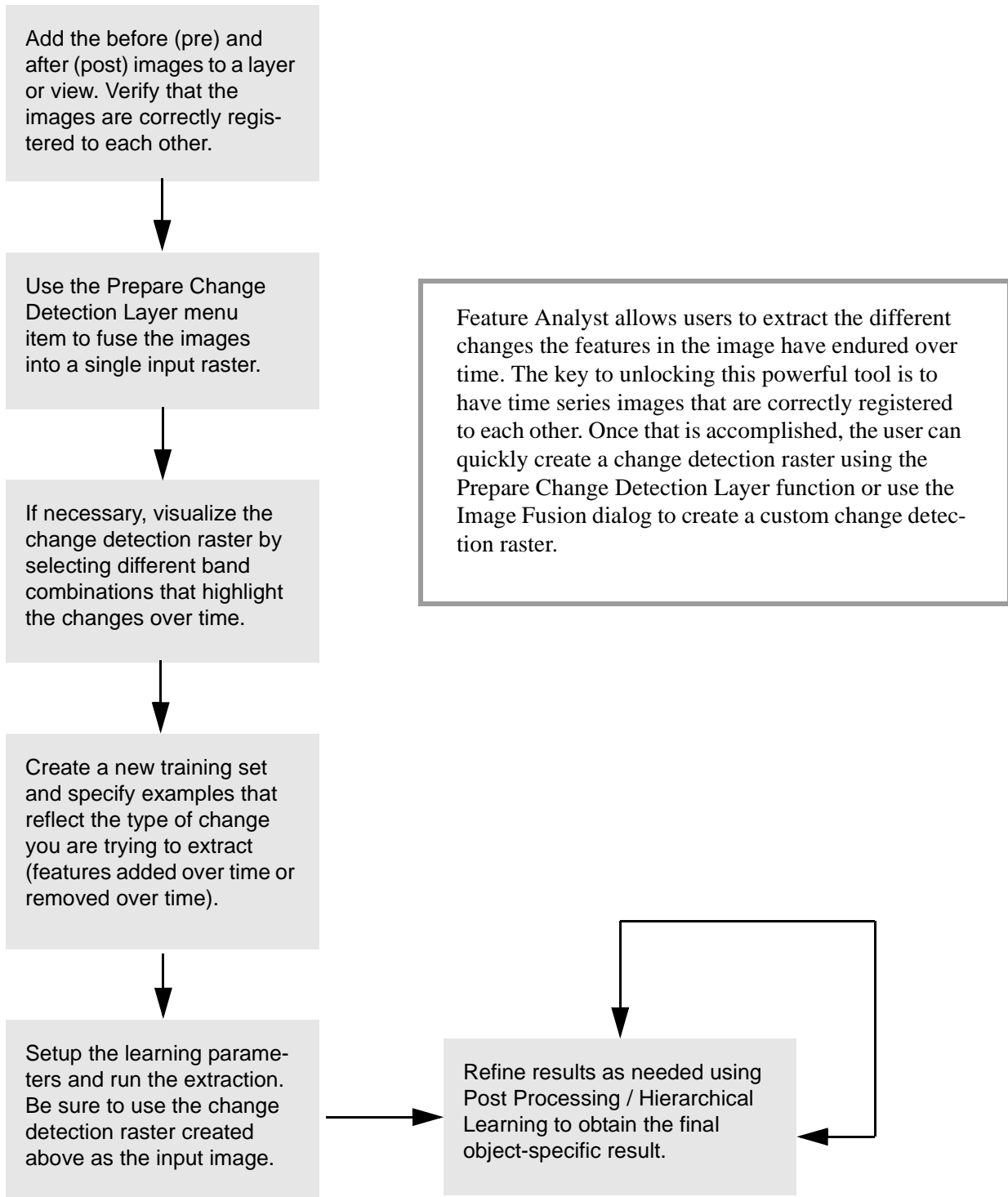
Feature Analyst’s machine learning approach to automated feature extraction incorporates software agent technology which *learns* to find features like hydrology, vegetation, and other land cover feature based on user-specified examples. The software provides *object-specific* feature capture technology using spatial context and advanced machine learning techniques that allow you to control the feature extraction process rather than using hard-coded rule bases. Built as an extension to ESRI’s ArcView 3.x., ArcGIS 8.x, and ERDAS IMAGINE, VLS designed Feature Analyst for GIS Analysts and technicians with minimal knowledge of image process technology and yet it is powerful enough for expert image analysts. It integrates advanced image processing transformations, such as Spectral Mixture Analysis into the feature extraction process.

Benefits:	Solutions For:
Automation: Reduces the labor costs of updating GIS databases.	Forestry: land cover, land use, roads, species identification, trails, trees, burn areas, fuels loads, and water.
Accuracy: More accurate than hand digitizing on many features. More accurate than image processing on almost all features.	State/Local Gov’t.: buildings, roads, impervious and pervious surfaces, paint on pavement, weeds, and riparian zones.
Simplicity: User-friendly interface allows for unparalleled ease-of-use. Absolutely no image processing expertise required.	Natural Resources: wetlands, soil classification, hydrology, shorelines, vegetation, and weeds.
Innovation: Department of Defense and NASA machine learning research producing spatial context, clutter removal, intelligent agent, & more.	Small Feature Capture: manhole covers, swimming pools, telephone poles, guardrails, and cars.

Cost-Benefit Analysis for Feature Extraction Techniques for the 1999 Multi-Modality Image Fusion Project



SUGGESTED CHANGE DETECTION WORKFLOW

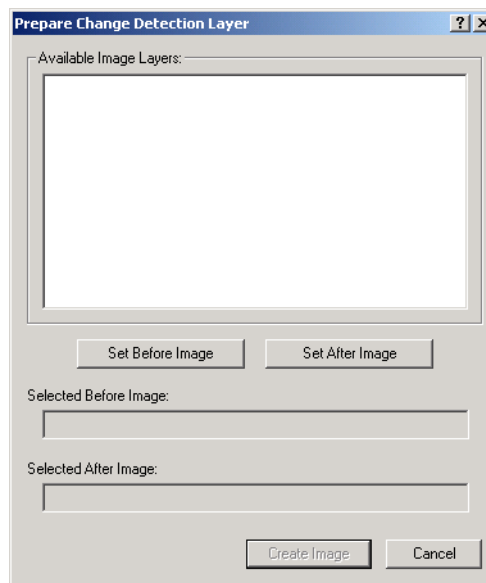
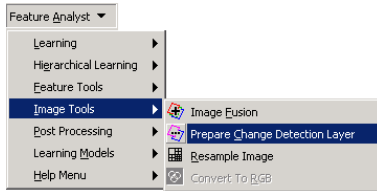


PERFORMING OBJECT-SPECIFIC CHANGE DETECTION

To perform change detection you must merge the before and after images while accentuating the differences between them.

Preparing the Change Detection Raster

- 1 Create a new data frame and add the before image (pre) and after image (post).
- 2 Choose **Feature Analyst** on the tool bar and select **Image tools**.
- 3 .Select **Prepare Change Detection Layer** on the Image Tools menu.



The Prepare Change Detection dialog box opens.

- 4 Highlight the before image and choose the **Set Before Image** button.

The image appears in the Selected Before Image field.

- 5 Highlight the after image and choose the **Set After Image** button.

The image appears in the Selected After Image field.

- 6 Choose **Create Image** to fuse the images.

The dialog box closes and the newly created raster appears into the layer in the Table of Contents.

Visualizing the Change Detection Raster

Visualizing the change detection raster allows you to easily see the changes that have occurred in an image over time. By default, when Feature Analyst loads a newly created change detection raster into the Table of Contents, it automatically sets the displayed bands to be the following:

When the input rasters are both RGB color images:	When the Input rasters are both panchromatic images:
The displayed red band is the red band from the before image.	Feature Analyst asks you if you want to add an extra band to the fused raster to allow for better visualization. <i>* The extra band contains no information and is added so an RGB composite display can be used.</i>
The displayed blue band is the blue band from the after image.	
The displayed green band is the green band from the after image.	

The band combination produces the following effects:

- Areas that have a reddish tint indicate features removed over time.
- Areas that have a blue-green tint indicate features added over time.

Tip:

To alter the default visualization, double-click on the change detection raster in the Table of Contents, select the Symbology tab, and then change the band combination.

Creating the Training Set



- 1 Choose **Create New Theme** and create a new shape file for the target feature type.
- 2 Select the **feature type** (polygon, line, or point) and enter a **name** and **location** for the new shape file.
- 3 Choose **Editor** on the menu bar and select Enable Editing.
- 4 Begin editing the shape file and specify examples that represent the type of change in the target feature you wish to extract.
- 5 When finished digitizing features, select **Stop Editing** from the Editor menu.

Tip: You should periodically save your edits with the Save Edit option on the Editor drop-down menu.

Setting up the Learning Parameters



- 1 Highlight the newly created shape file and choose the **Set Up Learning Button**.

2 There are two ways to set up the learning parameters:

Quick Setup:	Fine-tuned setup:
Choose Feature Selector tab on the Set Up Learning dialog box.	Choose Learning Settings tab on the Set Up Learning dialog box.
Select the option that most closely matches your desired features.	Verify that the change detection raster appears in the Active Image field and that the correct bands are selected in the Bands Selected scroll box.
Enter the image resolution in the <i>Select the resolution closest to that of your image</i> field.	Choose the Input Representation tab and select the input representation you want to use.
Choose OK.	Set the appropriate Input Pattern for you extraction problem.
	If necessary, specify the masking type.
	Choose the Learning tab and specify your aggregation size.
	Choose OK.



3 Choose **One Button Learning** to begin your extraction.

Finalizing the results

After the first extraction pass, Feature Analyst returns a generalized result that includes a variety of feature classes that share similarities with your examples. For example, if you were trying to extract a road that has been added over time, the first pass of learning might return not only the roads that have been added, but also vegetation that has been added over time. To refine the result, use a combination of Post Processing functions (Aggregate, Convert To Line, hand editing, etc.) and Hierarchical Learning (Remove Clutter and Add Missed).

A REAL WORLD CHANGE DETECTION EXAMPLE

The following is an example of how clients are using Feature Analyst to perform object-specific change detection and their reviews of the software’s performance.

U.S. Forest Service

One experiment compared the change detection capability of Feature Analyst and its state-of-the-art change-detection algorithms on an existing U.S. Forest

Service task of mapping the extent and severity of wildfires that burned large areas in Montana and Idaho during the summer of 2000.

The Region 1 Forest Service contracted with the Wildlife Spatial Analysis Lab (WSAL) at The University of Montana¹ to evaluate several change detection methods for mapping fire severity from multi-date, Landsat TM imagery. The WSAL is an internationally known laboratory specializing in image processing, GIS, and Forestry issues. WSAL analysts chose two popular state-of-the-art change detection methods: Normalized Difference Band Ratios (ND), and Principal Component Analysis (PCA). VLS approached the WSAL about using Feature Analyst in its study as a method of direct comparison to these techniques. WSAL agreed and controlled all reporting of experimental results. The WSAL provided VLS with training instances for land-cover classes that resulted in approximately 180 examples for the software agent. VLS delivered a classified image using these examples and WSAL reported correctness.

Table 1: Comparison of mean test-set accuracies by group and class for the three different methods

Group	Class	Feature Analyst	PCA 2/5	ND4/5
Burned	Lethal Tree	100%	75%	90.9%
	Mixed Tree	100%	87.5%	85.7%
	Shrub	66.7%	0%	0%
	Grass	83.3%	43.8%	44.4%
Unburned	Forest	83.3%	70%	58.3%
	Shrub	60%	25%	20%
	Grass	100%	38.1%	26.8%
Overall		80.6%	54.2%	50%

Overall, Feature Analyst classified the image into thematically correct classes substantially better than either the PCA or image-differencing classifiers (80.6% overall versus below 55% for the other two). When classifying non-burn vegetation, Feature Analyst classified 83% of the forest, 60% of the shrub, and 100% of the grass correctly; the other two had classification accuracies of only 70%, 25%, and 28% respectively. Feature Analyst produced superior results within the burn perimeter.

The most important classification for determining future fuel loads is to adequately distinguish between lethal and mixed-tree burns. Feature Analyst was 100% correct in determining these classes, while the other two techniques obtained an accuracy level of approximately 88%. Feature Analyst was substantially better in predicting burned grass and shrub as well (67% and 84% respectively, versus 0% and 44%).

1. Directed by Roly Redmond. See supporting letter.

Feature Analyst was more accurate than existing semi-automated change detection methods on a problem traditionally thought to be conducive to these techniques.

Feature Analyst was easier and more straightforward to use. The process was simply to push a few buttons using the adaptive user interface once the training points were established. The other two techniques required an expert image analyst.

Feature Analyst saved considerable labor costs. The WSAL analysts expended 10-20 times the labor effort on the “state-of-the-art” techniques than was expended with Feature Analyst. The WSAL also wanted to compare to hand digitizing, but labor requirements made this prohibitive.

SUMMARY

Feature Analyst addresses the labor costs and time issues of maintaining GIS databases using high-resolution imagery. The Feature Analyst extension for ArcView 3.x and ArcGIS 8.x provides a solution for this problem by integrating advanced machine learning technology into the GIS workflow. The software is simple, affordable, accurate, and fast. Feature Analyst excels at capturing land cover features using data from very high-resolution color and multi-spectral imagery to lower resolution panchromatic data. Feature Analyst is designed for organizations interested in saving time and money by:

- Utilizing the information content of high-resolution imagery with state-of-the-art technology.
- Using ESRI’s ArcView and ArcGIS software to manage the workflow of extracting information from high-resolution imagery.
- Extracting geospatial information from imagery to maintain the spatial and temporal content of your enterprise GIS database.
- Minimizing training requirements for GIS analysts and technicians, and/or providing added features for advanced image processing analysts.

REFERENCES AND SUGGESTED READING

Redmond, R. and Winne, C. (2001). Classifying and Mapping Wildfire Severity. *Imaging Notes*, v16(5), pp. 24-25.

Visual Learning Systems (2002). *User Manual, Feature Analyst Extension for ArcView 3.x/ArcGIS 8.x*, Visual Learning Systems, Inc., Missoula, MT.