Using ENVI and Geographic Information Systems (GIS)

Whitepaper
Introduction:

GIS (Geographic Information System) professionals recognize that imagery is essential for understanding what is happening in the world, learning how the environment is changing, and giving context to other types of data. Image availability, the power of its information content and the number of dissemination methods are rapidly increasing. While digital orthophotography is an essential element in a GIS professional’s geospatial data store, high resolution color and multi-spectral satellite imagery is also coming into common use. As the spatial and spectral fidelity of these sources improve, so does the ability to extract information important to GIS professionals.

One of the most common applications is the use of imagery as a data source to populate, update and assess the quality of GIS databases. Map accurate orthophotos or satellite images are used to collect (digitize) features such as road centerlines, land use areas, building footprints and utility infrastructure. Up-to-date imagery makes it easy to identify areas of development not yet captured in the GIS database. Automated image processing methods tailored for feature extraction can be used to reduce the effort of often tedious digitizing tasks of this type.

Other applications exploit the spectral content of the imagery to accomplish land use and land cover mapping; measure, monitor and assess environmental conditions; assess the condition of pavement and other public works assets; and identify building materials. Change detection is also possible when imagery is collected over time. The knowledge gained from these analyses is invaluable as input to land development models and forecasts, environmental impact statements, asset management budgets and reports for communicating important issues to community constituents.

A major focus of recent and future ENVI development is providing tools and methods to extract information from images, and to then integrate these results with GIS databases. ENVI currently has many tools for these purposes, including workflows for common image processing tasks for GIS professionals, converting to and editing common vector data formats, and geodatabase support. Moreover, upcoming releases will improve and add to these capabilities.

In the most recent version of ENVI, 4.7, there are even more tools to support a variety of GIS image processing tasks, using panchromatic, multispectral, or hyperspectral data. These efficient workflow tools include Change Detection, Image Classification, Orthorectification, Feature Extraction, and the SPEAR Tools, a suite of wizards for performing common image processing tasks. Other GIS functionality in ENVI includes the capability to create maps and reports from existing map templates and the ability to drag and drop layer files between ENVI and ArcGIS.
Data Access and Geodatabase Support

ENVI supports imagery types gathered from numerous satellite and airborne sensors including panchromatic, multispectral, hyperspectral, radar, thermal, LiDAR, and more. ENVI can read over 70 data formats and includes HDF, GeoTIFF, JPEG and JPEG2000. And, ENVI also delivers enterprise capabilities that allow users to quickly and easily access imagery from OGC and JPIP compliant servers within organizations or over the internet.

Geodatabase and enterprise connectivity is important for ENVI, as more and more companies and organizations are providing their image data to constituents by setting up databases on centralized server machines. For the members of the enterprise to access these images across the internet or other network, they need appropriate software on their local (client) machines. Making ENVI a client to these remote databases allows the enterprise members to use ENVI to smoothly access the imagery that they need as part of their GIS and image analysis workflow.

ENVI supports file access to and from the ArcGIS Geodatabase, so users can seamlessly open data from the ArcGIS Geodatabase in ENVI, perform image analysis, and then save the results back into the geodatabase. ENVI supports personal, file, and enterprise geodatabases.

Additionally, ENVI is enabled as a client to Open Geospatial Consortium (OGC) compliant servers.

The two OGC service standards supported in ENVI are:

- **WMS (Web Map Service):** WMS is a protocol for serving maps that are generated on-the-fly for display purposes only. A powerful feature of WMS servers is that you can identify multiple datasets that meet your criteria, and the server combines them into one displayable map layer.

- **WCS (Web Coverage Service):** WCS is a protocol for serving raster data that represent properties of geographic locations. WCS servers provide coverages that can be used for quantitative analysis.
Image Processing Workflows for GIS

ENVI’s intuitive user interface and easy-to-use tools allow users to quickly and easily view and explore imagery. ENVI can be used to view large datasets and metadata, visually compare imagery, create powerful 3D visualizations, create scatter plots, explore pixel signatures, and more.

ENVI provides a complete suite of tools based on proven scientific methods to help analyze imagery. With ENVI you can:

- Orthorectify imagery
- Detect change
- Register two or more images
- Classify imagery using supervised and unsupervised methods
- Create vector overlays
- Detect and identify targets
- Identify regions of interest (ROIs)
- Identify features of interest
- Create digital elevation models (DEMs) and model topographic characteristics
- Analyze and map materials of interest
- Calculate forest health with vegetation analysis tools
- Use post classification tools to refine results
- Extract Features
- Use SPEAR Workflow tools

Change Detection

The landscape changes continually as a result of human and natural forces. Change detection is a process that measures how the characteristics of a particular area have changed between two or more time periods. Change detection can be accomplished using satellite imagery or aerial photography, advanced image processing techniques, and GIS analysis to map the spatial location and magnitude of land cover change. Performing a change detection analysis encompasses a broad range of methods used to identify, describe, and quantify the differences between the images, which were acquired at different times and under different conditions. A user may use many of ENVI’s tools independently or in combination as part of a change detection analysis.

When performing a change detection study, there are two types of change detection: absolute change and relative change. Absolute change detection highlights specifically what has changed – for example, a forest class that has changed to a grassland class. Relative change detection shows that something has changed, but does not specify what that change is. ENVI offers a variety of change detection methods; depending on what type of analysis is needed, the user can choose between the different methods to suit the particular project’s needs.
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- **Image Transform**: Input datasets are stacked into one image cube, then an image transform (principle component analysis, minimum noise fraction, or independent components analysis) is applied in order to extract the feature correlating to change.

- **Image Ratio and Subtractive Methods**: Normalized Difference Vegetation Index (NDVI), red/blue ratio, and man-made ratio are calculated for the input datasets. The resulting ratios and input bands are subtracted from the input images to create difference images (Figure 1).

![Figure 1: Image Ratio Change Detection](image)

- **Image Difference or Subtractive**: This method produces an ENVI classification image characterizing the differences between any pair of initial state and final state images. The difference is computed by subtracting the initial state image from the final state image (that is, final - initial), and the classes are defined by change thresholds. A positive change identifies pixels that became brighter (final state brightness was greater than the initial state brightness), while a negative change identifies pixels that became dimmer (final state brightness was less than initial state brightness).

- **Two Color Multi-View (2CMV)**: A 2CMV change detection product shows one band from the Time 1 image displayed in the red band and the same band in the Time 2 image displayed in the green and blue bands. Objects that display a difference that is brighter from one image to the other appear in cyan. Objects that display a difference that is darker from one image to the other appear in red. The colors can then be used to indicate potential areas of change (Figure 2).
Thematic Change: The workflow for thematic change detection is to first perform an image classification on each image. Then the subtractive change detection is performed on the two classification images. The change detection result is a thematic change classification image, showing the results from one class change to another. This method is useful to understand how classification regions have changed over time (Figure 3).

Figure 2: The image on the left is the “before” scene, the middle image is the “after” scene, and a 2CMV change detection visualization result is shown at the far right. The areas that have been removed from Time 1 to Time 2 are shown in red, and the areas that are new between Time 1 and Time 2 are shown in cyan.

Figure 3: Thematic change detection operates on classification images, subtracting the classification of Time 1 from the classification of Time 2. At left, the resulting thematic change detection statistics are shown. The matrix shows how classes have changed from Time 1 to Time 2; for example, areas that were classified as trees in Time 1 are now classified as Ground in Time 2.
Image Classification

For panchromatic, multispectral, and hyperspectral data, ENVI has numerous methods for automatically categorizing pixels into specific classes. Image data classified in this way can then be converted to vector layers and output to a variety of vector formats, such as shapefiles, or saved to the ArcGIS geodatabase. The classification images can be used for reference maps to conduct change detection, monitoring of new development, or quantifying land cover types.

The goal of classifying features in an image is to identify homogeneous groups of pixels which represent various features or land cover classes of interest. Classification assigns each image pixel to a particular class, such as water, forest, urban area, and agricultural fields – producing a thematic “map” of the original image.

ENVI’s classification workflows include two different methods, depending on whether or not the user has classification training data:

- In a supervised classification, the user selects representative samples of the different surface cover types from the image. These samples are referred to as training areas. The ENVI classification algorithms use the training data to learn what each class ‘looks like’ in multi- or hyper-spectral data space. Once the user selects the training areas, then ENVI will perform the classification based on these training areas for the entire image (Figure 4).

- In an unsupervised classification, ENVI uses an automated technique that searches for natural groups, or clusters, of pixels based on their brightness in several bands. Unlike the supervised method, unsupervised classification does not begin with a predefined set of classes. Here the user will define (i.e., label) what the grouped regions in the unsupervised results represent (Figure 5).

ENVI’s Supervised Classification methods include:

- Parallelepiped
- NMahalanobis Distance
- Maximum Likelihood
- Minimum Distance
- Spectral Angle Mapper (SAM)
- Spectral Information Divergence (SID)
- Support Vector Machine
- Binary Encoding
- Neural Net
- Winner Takes All
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ENVI’s unsupervised classification methods include:

- K-Means
- ISODATA

Figure 4: ENVI contains 10 supervised classification methods to create thematic data maps. The original input image is shown at the far left. Using the ENVI Region of Interest (ROI) tool (shown in the middle), the user can draw representative areas on the image. A Neural Net classification map result is shown at right.

Figure 5: In an unsupervised classification, a thematic map of the input image is created automatically in ENVI without requiring any pre-existing knowledge of the input image. The input image is shown at left and the K-Means result is shown at right. The unsupervised classification method performs an automatic grouping; the next step in this workflow is for the user to assign names to each of the automatically generated regions (for example, the red class would be named “Water”).
Post Classification Clean Up

After performing an image classification, the next step in the workflow is to perform a clean-up of the classification data. Classification results often contain scattered individual pixels of one class surrounded by a larger area of another class and it is useful to clean up the data in preparation for export to a vector file or for enhanced display (Figure 6).

ENVI provides a number of tools, including clumping, sieving, and majority analysis, for minimizing this type of clutter in classification results, providing smoother results for improved GIS visualization and spatial analysis.

Vector Tools

The power of vector data is in its ability to provide any type of attribute information for any point, polyline, or polygon. Additionally, vector and raster data are complimentary to one another for analysis, display, and data sharing tasks. Users may use imagery to give contextual information to vectors, and also use the image to extract information to either obtain new vectors layers or update exiting vector ones.

ENVI supports output of vector data to its own vector format (ENVI Vector Format or .EVF), as well as to shapefiles and other formats. ENVI also provides the ability to create new vector layers via heads-up digitizing from image data, edit existing vector layers, and query vector attributes.

ENVI has tools for vector editing vectors, including the ability to create new layers, edit existing vertices, group and merge vectors, and to also remove holes from polygons (Figure 7).
Figure 7: Easy to use context menus in ENVI allow users to perform common vector editing tasks. The vector result shown here is of a precision agriculture feature extraction process in ENVI. Depending on the desired final result, a user may wish to have only the entire parcel as one polygon, or the user may want each distinct region in the parcel as a separate vector. To remove the inside vectors, a simple operation in ENVI is to select the vector and “remove holes.”

**SPEAR Workflow Tools**

A unique set of automated capabilities in ENVI now allow you to perform spectral image processing quickly and easily. The ENVI Spectral Processing Exploitation and Analysis Resource (SPEAR) Tools, which are included with the core ENVI software, automate many common image processing tasks into workflows. Designed with the imagery analyst and geospatial analyst in mind, these unique wizards greatly reduce the time and effort required to pan-sharpen, detect change, categorize terrain, and more. The tools include step-by-step instructions, with integrated help and information dialogues that walk users through complex image processing routines to produce advanced value-added imagery products (Figure 8).
The SPEAR tools include fifteen different workflows, all optimized for multispectral imagery. Advanced or novice users can quickly and accurately create results and reports with little or no additional training. By leveraging the powerful and proven tools already in ENVI within task specific workflows, SPEAR provides users with a simple and reliable way to generate results, streamlining the user’s workflow and increasing efficiency.

The following workflows are available in SPEAR:

- Anomaly Detection
- Pan Sharpening
- Change Detection
- Relative Water Depth
- Google Earth Bridge
- Spectral Analogues
- Image-to-Map Registration
- TERCAT (Terrain Categorization)
- Independent Components Analysis
- Vegetation Delineation and Stress Detection
- Lines of Communication
- Vertical Stripe Removal
- Metadata Browser
- Watercraft Finder
- Terrain-based Orthorectification

The workflow tools have been optimized for a variety of data, and results can be sent to Geographic Information System (GIS) databases, Google Earth, or pushed directly to ArcGIS for map and report creation.
Feature Extraction

Users need fast and accurate methods to locate, identify and extract features of interest. Manually locating and digitizing these features from imagery is often tedious and time consuming, especially over large coverage areas. Furthermore, limited spectral content may make standard pixel based classification and extraction approaches too inaccurate to be effective. The ENVI Feature Extraction Module (ENVI Fx) uses an object-based approach that can be used on high spatial resolution imagery with limited or no spectral content. ENVI Fx allows GIS professionals to automatically extract spatial objects from imagery and reduce the time spent on manual processes.

ENVI Fx can be used to extract a wide variety of features such as vehicles, buildings, roads, bridges, rivers, lakes, and fields, and is optimized for extracting information from high-resolution panchromatic and multispectral imagery based on spatial, spectral, and texture characteristics. Additional datasets, such as a raster LiDAR elevation dataset, can be added to the workflow to enhance results.

The ENVI Feature Extraction Module is ideal for:

- Finding and counting particular features across large images
- Adding and updating vector layers to geodatabases
- Classifying images as outputs to be used in reports or analyses
- Replacing or accelerating manual digitization processes

The ENVI Feature Extraction Module uses an object-based approach to identify and define features, allowing users to get accurate results even with limited bands. With popular high-resolution panchromatic or multispectral imagery that is commonly in use today, an object-based method offers more flexibility in the types of features to be extracted.

One of the most efficient and innovative aspects of ENVI Fx is the ability to preview results at each step of the workflow. The preview portal shows on-the-fly results of parameter adjustments and can be resized and moved around the image, to make sure that the features of interest are being located in all areas of the scene (Figure 9). Once suitable parameters have been established, the process can be automatically repeated on a collection of imagery.
Data Sharing

ENVI easily integrates into existing GIS workflows, allowing users to share maps and reports with colleagues. ENVI also has versatile output and “save as” options. Processed images can be output to common vector and raster formats for collaboration and presentation.

ENVI also supports file access to and from the ArcGIS Geodatabase, so users can seamlessly open data from the ArcGIS Geodatabase in ENVI, perform image analysis, and then save the results back into the geodatabase. For Geodatabase access, ENVI supports reading and writing to personal, file, and enterprise geodatabases. Optionally, users can push data directly from ENVI into ArcMap for quick display options.
ENVI has numerous interactive tools to view and analyze vectors and GIS attributes. Displayed layer files in ArcMap can be opened directly in ENVI, allowing for seamless and shared data analysis in both software packages (Figure 9). For example, layer files opened in ArcMap can be brought into ENVI, so the user can perform a feature extraction using the layer files as boundaries.
Map Composition

ENVI 4.7 introduces a new Layout View for map composition (Figure 11). Following completion of an image analysis workflow, users can switch to an ENVI Layout view and apply a ESRI map template file to their ENVI data. Editing, resizing, and repositioning of the data inside the layout view allows for numerous customization capabilities to quickly disseminate results to colleagues.

Figure 11: The new Map Layout view in ENVI allows users to take image processing and feature extraction results and apply an ESRI map template for map composition, all from within the ENVI interface.
Conclusion

ITT Visual Information Solutions recognizes the growing importance of having ENVI functionality integrate with a GIS workflow for fast and accurate results. Image processing workflow tools with customers’ solutions and products in mind increases the effectiveness of the software and the efficiency of the operation. ENVI currently provides a number of these tools that can help users of all backgrounds integrate imagery into their daily workflows. Moreover, development plans for ENVI include many new workflow tools that will make image processing even easier.

To learn more about ENVI features and functionality and the available GIS tools, visit http://www.ittvis.com/ProductServices/ENVI.aspx or contact your ENVI sales representative at 303-786-9900.