LAUR-06-7976

Overview of Genie Pro™

Executive Summary:

Genie Pro is an adaptive automatic feature extraction (AFE) software tool that can be applied to a wide range of applications, including Earth remote sensing and biomedical imagery applications (photos to the right). The software uses techniques from statistical machine learning theory and evolutionary computation theory (genetic programming with grammars) to perform robust and customized AFE in multispectral, hyperspectral, panchromatic, and multi-instrument fused imagery. Genie Pro represents a significant technical advance beyond the simple image classification algorithms found in popular geospatial information system (GIS) packages. Genie Pro is able to distinguish between similar features that share similar spectral characteristics (e.g., asphalt roads vs. asphalt roofs) by considering the spatial context of each pixel, which enables it to produce accurate map overlays on tasks that would defeat traditional classification algorithms. The results are automatically refined using adaptive morphological filtering, and outline and centroid vectorization algorithms allow results to be exported to standard GIS systems.

Figure 1

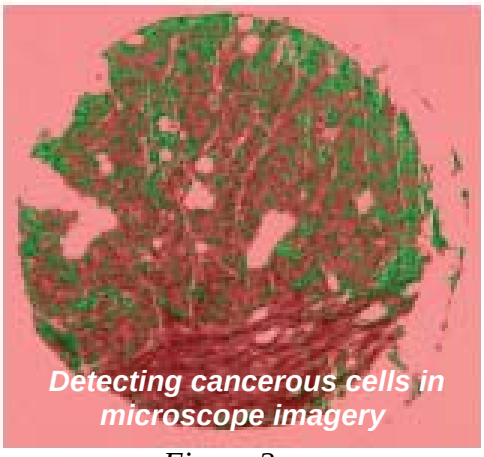


Figure 2

Figure 3

No programming skills are required to use Genie Pro: the machine learning system is trained to solve problems using an intuitive, point-and-click graphical user interface. The algorithms produced by Genie Pro can be applied to new images, and can be analyzed to determine the signatures of the features of interest. Genie Pro runs on standard off-the-shelf Windows and Linux workstations. Genie Pro was developed by the Intelligent Searching of Images and Signals Team in the International, Space and Response Division at Los Alamos National Laboratory.

Development Stage: Software is ready for commercial launch and sales.

Intellectual Property Status: Copyright protected.

Licensing Status: Available for licensing.

The Technology:

Genie Pro is a software package that builds automated feature extraction (AFE) algorithms. Genie Pro uses a library of basic image processing operations and a grammar-guided evolutionary algorithm to build non-linear spatio-spectral image processing algorithms (where spatial processing includes textural and morphological processing) that define a pixel attribute space in which a supervised statistical classifier can learn a decision surface that separates pixels containing the feature of interest from background pixels. This attribute space can provide interesting visualizations of the data and can be analyzed to investigate the signatures of the feature of interest. The image processing library of primitives and grammar can be modified and/or extended based on the feature extraction task and data available. Genie Pro can run in binary or multi-class classification mode. It returns a raster result image with pixel values encoding category label and/or strength of detection of the feature in that pixel. The algorithm makes no assumptions about the type of imagery, and so can be used to learn algorithms for processing data from multiple sensors or multiple epochs (for change detection applications), provided that these images have been co-registered and re-sampled to have matching ground sample distance and projection. Genie Pro vectorizes connected regions in its raster result image into polygons that can be exported to standard geospatial information system (GIS) software. (See "*Genie Pro: Robust Image Classification using Shape, Texture, and Spectral Information*" for a detailed technical overview).

Major components of Genie Pro:

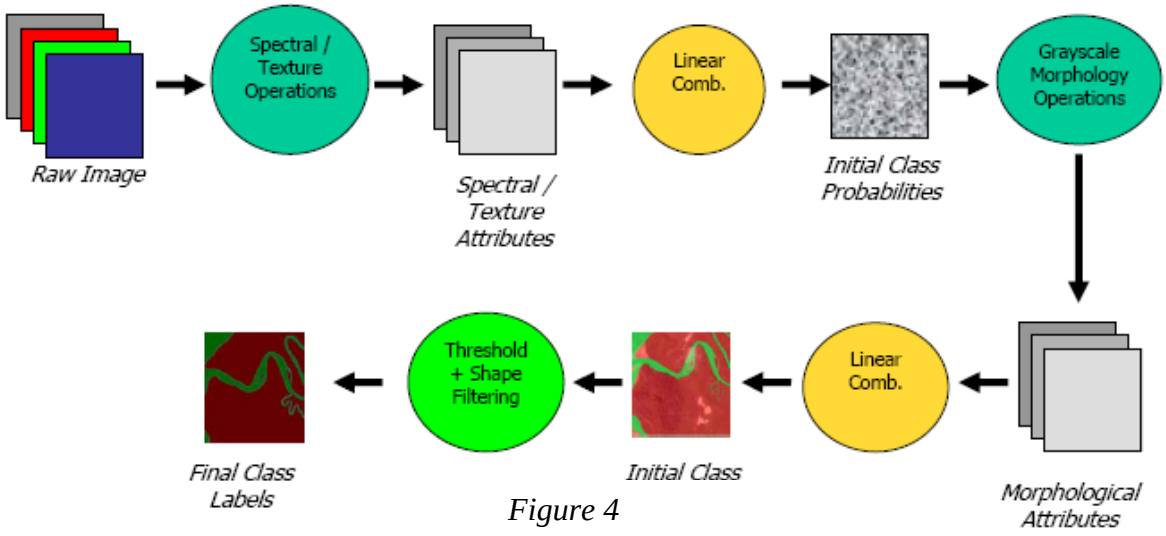


Figure 4

The major components of Genie Pro are:

1. a graphical user interface (GUI) for providing training data and inspecting results (See the Genie Pro tutorial: *"Getting Started with Genie Pro"* for an example of the user interface),

2. an adaptive spectral/textural image processing stage for learning the attributes of pixels containing the feature of interest,
3. an adaptive morphological image processing stage for refining the results of the spectral/textural image processing stage,
4. a supervised statistical classifier (regularized maximum likelihood Gaussian classifier) that uses the training data from the GUI and the attributes found by the spectral/textural and morphological image processing stages to determine the decision rules for extracting the feature of interest,
5. an adaptive thresholding algorithm that takes the result of the statistical classifier and produces a raster map of the feature of interest in the image,
6. a vectorization algorithm designed to smoothly delineate raster regions containing the features of interest. This enables export of Genie Pro's results to standard GIS applications,
7. an algorithm visualization tool that enables analysis of evolved algorithms using any standard web browser.

Hardware/Software Requirements:

Genie Pro is written entirely in C++ for speed and compatibility. The graphical interface uses the Qt toolkit from Trolltech, Inc. (http://www.trolltech.com/products/qt), which provides a cross-platform windowing environment. The code is portable, and compiles and runs on both Windows and Unix-like environments, such as Linux. Genie Pro supports a wide variety of standard file-formats, using the popular open source GDAL library (http://www.remotesensing.org/gdal). Genie Pro runs on standard Windows and Linux workstations. Memory and processor requirements are comparable to other standard imagery analysis/geospatial information system (GIS) applications.

A typical Genie Pro Session:

A typical Genie Pro session proceeds as follows:

1. The image analyst loads an image into the Genie Pro graphical user interface.
2. The image analyst "marks up" the image using simple raster-based painting tools. The analyst indicates the locations of a few examples of different targets of interest as well as examples of regions where targets are absent.
3. The analyst hits the "Train" button, and Genie Pro attempts to use the training markup to derive a general pixel classifier.
4. After a short time, the analyst applies the resulting pixel classifier to other parts of the image and inspects the results. If the classifier has made some mistakes, the analyst has the option of adding more training data and continuing training, or of manually correcting the results by hand.

5. Once the analyst is happy with the pixel labeling, the final algorithm can be applied to the whole image or to other images in the archive, and a corresponding vector layer can be generated and exported for use in standard GIS applications.

See the Genie Pro tutorial *"Getting Started with Genie Pro"* for more information about using Genie Pro.

Real-world Applications and Awards:

With current sensor platforms collecting a flood of high-quality data, automatic feature extraction (AFE) has become a key to enabling human analysts to keep up with the flow. ISIS tools have been applied to a number of real word applications, including urban and natural disasters (wildfire, flooding), biomedical imagery (cancer and pathogen detection, space exploration (Mars and beyond), and national security missions for DOE and other US Government agencies. A peer-reviewed assessment of Genie Pro's approach to automated feature extraction has been published in *"Comparison of GENIE and Conventional Supervised Classifiers for Multispectral Image Feature Extraction"*, and in numerous publications of the research team available at http://www.genie.lanl.gov/publications. A detailed technical description of Genie Pro's algorithm has been published in the technical paper on Genie Pro, *"Genie Pro: Robust Image Classification using Shape, Texture, and Spectral Information"*.

The GENIE* algorithm technology behind Genie Pro won an *R&D Magazine* R&D100 Award (2002), and the GENIE team has received the LANL Distinguished Performance (Large Team) Award (2002). Genie Pro received LANL's Licensing Award: Copyright of the Year (2006).

*Note: Development on AFE research software began in 1999 and a Linux version of GENIE was released as open source. In 2003, the algorithm concepts behind GENIE were used to write a user-friendly, efficient, commercializable, and cross-platform (Windows and Linux) version of the software which is Genie Pro.

Independent Evaluation:

Genie Pro received the highest score in a recent government-sponsored evaluation of the software compared with three other commercially available packages designed to perform a similar task in an operational mapping environment. Genie Pro produced quality map overlays in less time than any of its competitors.

The summary of the "Evaluation of Feature Extraction" competition, or "Bake Off" by the National Geospatial Intelligence Agency (NGA) stated that "GENIE Pro had the best overall performance in terms of total extraction time. User feedback for GENIE Pro was also very favorable, indicating that GENIE performed well and was easy to use … Based on the results of this test, NGA is exploring ways to put these tools into the hands of users to support current production activities."

References:

[1] N. R. Harvey, J. Theiler, S. P. Brumby, S. Perkins, J. J. Szymanski, J. J. Bloch, R. B. Porter, M. Galassi, and A. C. Young. "Comparison of GENIE and Conventional Supervised Classifiers for Multispectral Image Feature Extraction." *IEEE Trans. Geoscience and Remote Sensing* **40** (2002) 393-404.

[2] S. Perkins, K. Edlund, D. Esch-Mosher, D. Eads, N. Harvey, and S. Brumby. "Genie Pro: Robust Image Classification using Shape, Texture, and Spectral Information." *Proc. SPIE* **5806** (2005) 139-148.

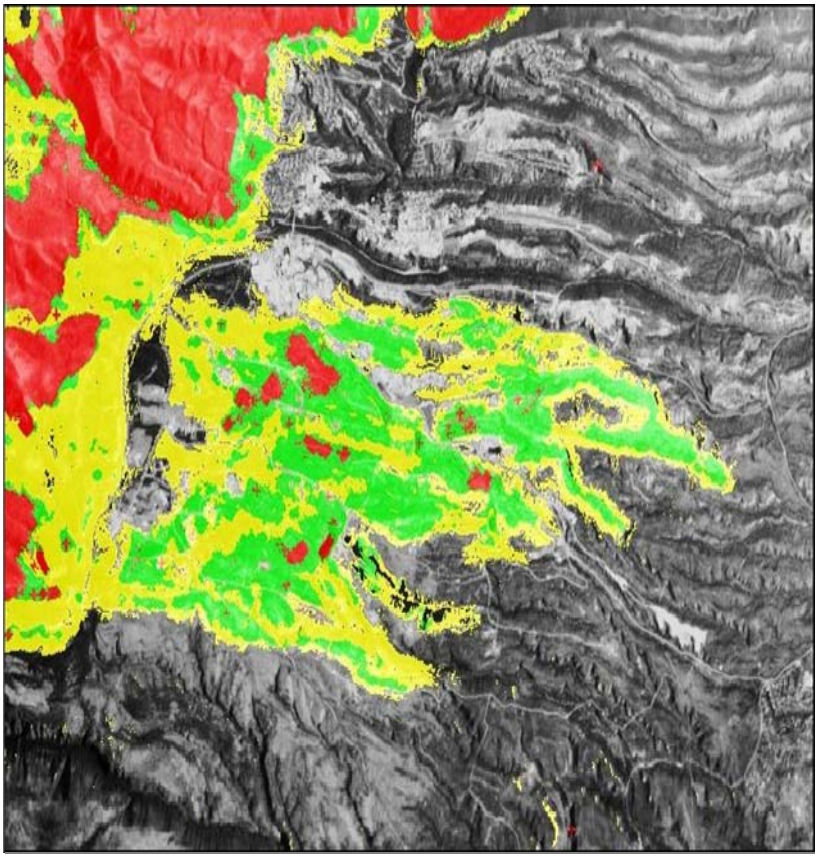
[3] "Evaluation of Feature Extraction Tools": Report on the "Bake-off" experiment conducted by the National Geospatial-Intelligence Agency (NGA) Geospatial Intelligence Advancement Testbed (GIAT) for the NGA Synergistic Targeting Auto-extraction and Registration (STAR) Program.

[4] Michael A. O'Brien, (2003) "Performance Evaluation of the GENIE System", *Proceedings of the American Society for Photogrammetry and Remote Sensing*, May 2003.

[5] http://www.trolltech.com/products/qt

[6] http://www.remotesensing.org/gdal

[7] "Genie Pro Tutorial", Genie Pro Team, 2005.



Identifying and mapping burn severity near Los Alamos in 2000