Recursive Hierarchical Image Segmentation

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Image Segmentation: A partitioning of an image into related sections or regions:

Image regions consist of image pixels having related data feature values.

- Data Feature Values may be the multispectral or hyperspectral data values themselves and/or derived features such as band ratios or textural features.

Image segmentation is a first step to several approaches to image analysis:

- Image segmentation provides (i) a statistical sampling for direct labeling of an entire region based on aggregated feature values, and (ii) a region shape that can be used as additional evidence for appropriate labeling.
- Can incorporate spatial information which often gives a more satisfactory analysis result.
- A basis for fast analysis since each image pixel need not be analyzed separately.
- Image compression can be based on image region maps and region feature lists.
- Can be a basis for Image Information (Data) Mining.

Hierarchical Image Segmentation:

A hierarchical image segmentation is a set of several image segmentations at different levels of segmentation detail in which the segmentations at coarser levels of detail can be produced from simple merges of regions from segmentations at finer levels of detail.

A unique feature of hierarchical image segmentation is the the segmented region boundaries are maintained at the full image spatial resolution at all levels of segmentation detail in the hierarchy.

Maintaining region boundaries at full image spatial resolution avoids compounding the "mixed pixel" problem which adversely impacts other multiresolution segmentation schemes in which the coarser resolution segmentations are produced from spatially degraded versions of the imagery data.

Approaches to Image Segmentation

Approach	Problem
Spectral Feature Clustering	Spatial Information not Utilized
Edge Detection	No Guarantee of Closed Connected Regions
Region Growing	Global Convergence Difficult and Compuationally Intensive

Solution adopted by the Recursive Hierarchical Segmentation (RHSEG) program: A recursive implementation of hybrid region growing and spectral feature clustering with a natural convergence criterion on parallel computers [1,2,3].

References

[1] James C. Tilton, "Image segmentation by region growing and spectral clustering with a natural convergence criterion," Proceedings of the 1998 International Geoscience and Remote Sensing Symposium, Seattle, WA, July 6-10, 1998.

[2] James C. Tilton, "Method for recursive hierarchical segmentation by region growing and spectral clustering with a natural convergence criterion," Disclosure of Invention and New Technology: NASA Case Number GSC 14,328-1, February 28, 2000. See also http://code935.gsfc.nasa.gov/code935/tilton.

[3] James C. Tilton, "Method for recursive implementation of hierarchical segmentation on parallel computers," Disclosure of Invention and New Technology: NASA Case Number GSC 14,305-1, February 2, 2000.

Patent Filings

- **A patent has been filed** on the fast implementation of Recursive Hierarchical Segmentation on parallel computers. This parallel implementation of the RHSEG program can process full Landsat TM scenes (roughly 8000x8000 pixels with 6 spectral bands) in 4 to 6 hours on the 128 processor HIVE (a Beowulf-type MIMD computer).
- **A preliminary patent has been filed** on approaches to (i) reduce the processing time RHSEG program and (ii) reduce or eliminate processing window artifacts due to the recursive division and recombination of the data during processing.

Processing Times on the HIVE

Image Size	Spectral Bands	Processing Time
128x128	6	up to 2 minutes
256x256	6	up to 4 minutes
512x512	6	up to 5 minutes
1024x1024	6	up to 9 minutes
2048x2048	6	up to 31 minutes

All times are for processing on the Beowulf cluster called the HIVE at the Goddard Space Flight Center. The HIVE consists of 64 dual-node Pentium Pro processors with a clock speed of 200-MHz.

Processing Times on a SUNUltra 80 Workstation

Image Size	Spectral Bands	Processing Time
128x128	6	4 mins 39 secs
256x256	6	22 mins 4secs
512x512	6	1 hr 37 mins
1024x1024	6	6 hrs 25 mins

All times are on a 450-MHz, single CPU SUNUltra 80 Workstation.

The Region Labeling Tool

A "Region Labeling Tool" has been developed to facilitate the selection of a particular application specific segmentation from the hierarchical set of segmentations produced by RHSEG algorithm. With this tool an analyst selects a particular data point, and all other data points in the same region in the segmentation (either at the finest level or coarsest level of detail) are highlighted. The analyst then can choose to adjust the level of segmentation detail by selecting other levels from the segmentation hierarchy. Other tools are available to adjust the highlighted areas. Once the analyst is satisfied with the areas highlighted, he/she can label the segment with a particular alphanumeric phrase and color. This process can be continued until the whole data set is labeled. A full description of this process, complete with graphics, is available at http://code935.gsfc.nasa.gov/code935/tilton.

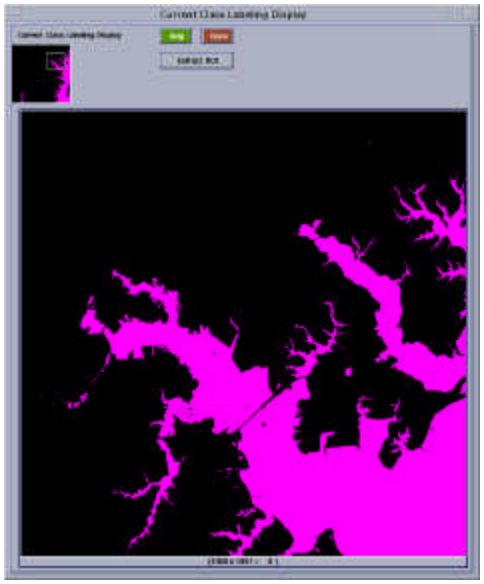
Application of Hierarchical Image Segmentation to Remotely Sensed Imagery Data

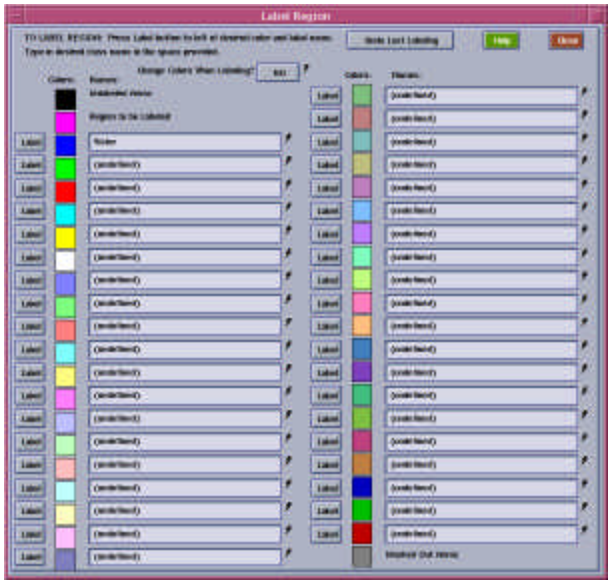
The potential of hierachical segmentation to remotely sensed imagery data mining can be best illustrated through an example of using the Region Labeling Tool. The data set used in this example is a six – band section of a Landsat TM image taken over the Washington, DC / Baltimore, MD area on September 16, 1991 (WRS II path/row 15/33). The thermal band was not used. The section used for the example is a 2504-by-2504 pixel section with the southwest corner approximately 8 miles west and 9 miles south of the center of Washington, DC (the White House), and the northeast corner approximately 12 miles north and 16 miles east of the center of Baltimore, MD (the Inner Harbor). Figure 1 shows an RGB rendition of this image data, with spectral band as read, band 4 as green, and band 2 as blue.

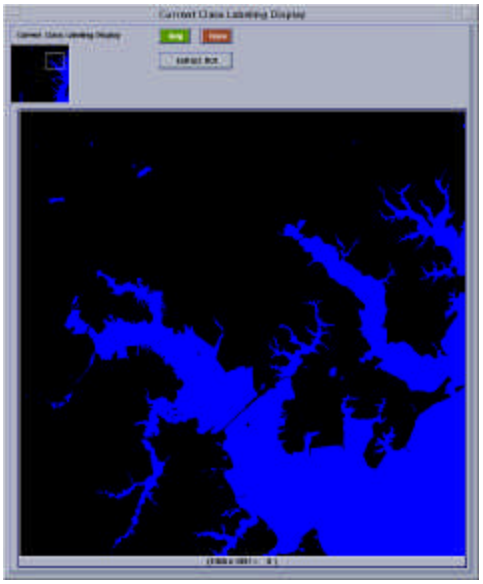
Application of HSEG (cont'd)

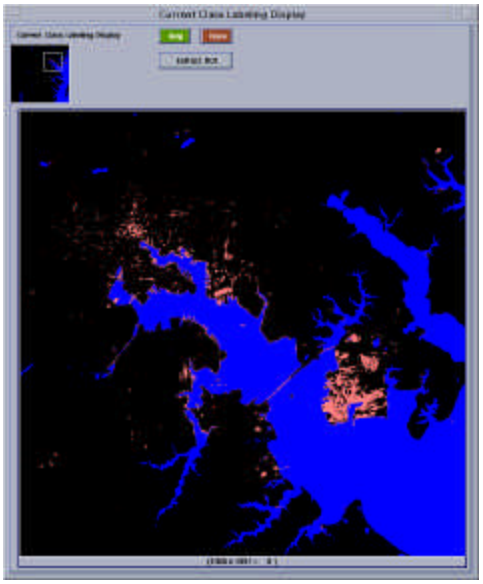
RHSEG was used to produce a 16-level hierarchical image segmentation of the Landsat TM image displayed in Figure 1. The inputs to the Region Labeling Tool are an RGB rendition of the data segmented, the region label map file, the region merges list, and the region feature lists for the region mean, number of pixels and criterion value. The outputs are a class label map and a class label name list.

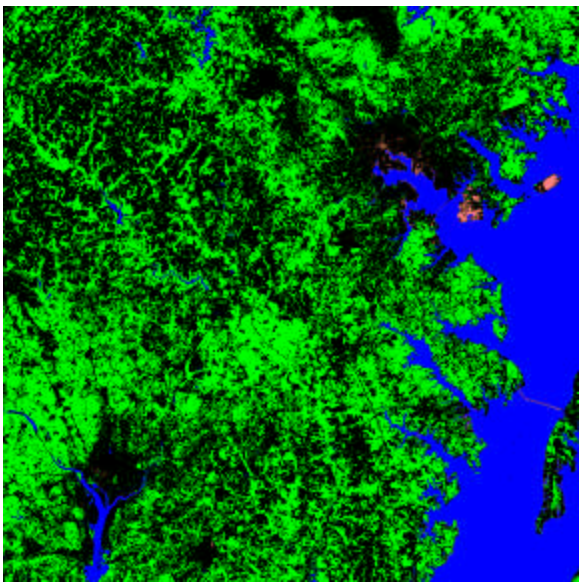
NOTE: Figure numberings in the following correspond to the numberings in the reference web page http://code935.gsfc.nasa.gov/code935/tilton/region_label_disclosure/figures/html .

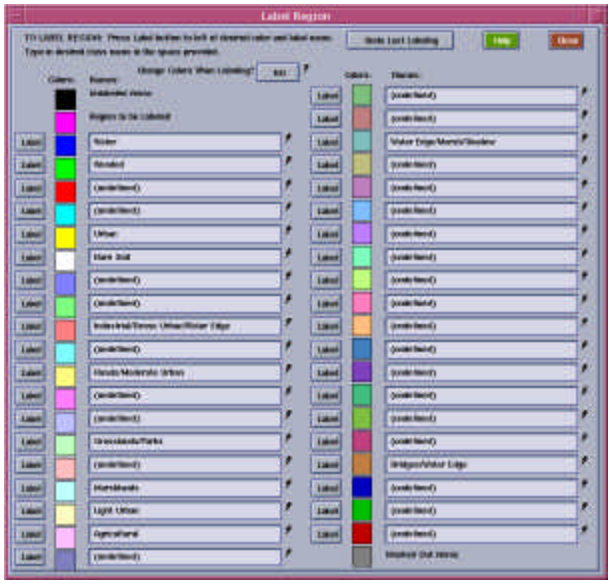


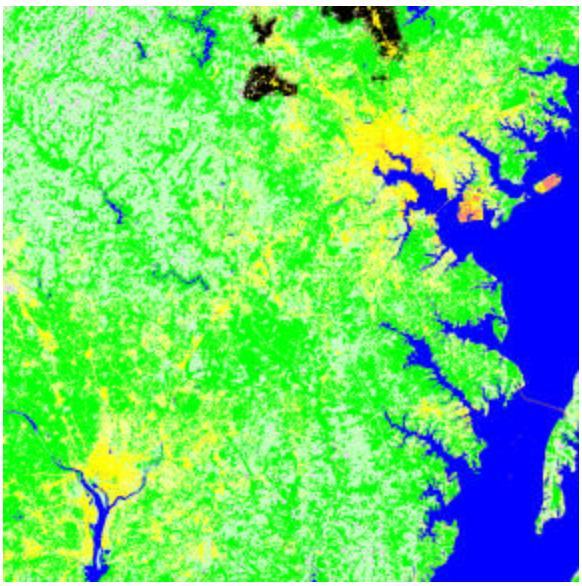


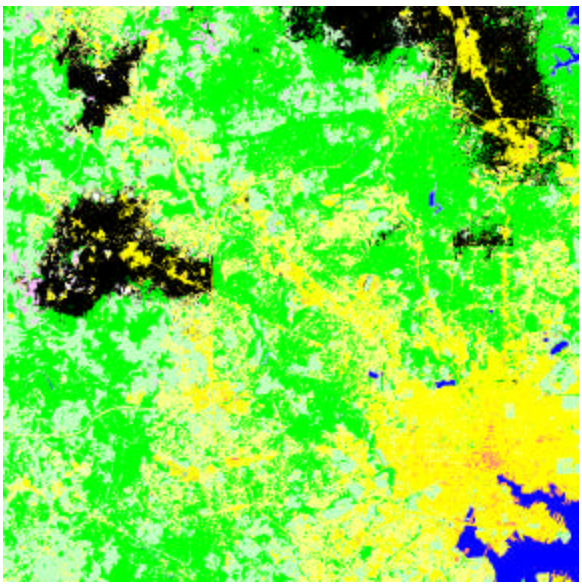












Potential Application of RHSEG to Medical Applications

Applications that could benefit from RHSEG would be those that:

- Require high quality image segmentation. The quality of the analysis of segmented data is very highly dependent on the quality of the underlying image segmentation.
- Would benefit from high level human interaction with a segmentation hierarchy to select the appropriate image segmentation for a particular application.
- Other???