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Progressively Segmented Image Modeling as Poly-Patterns
(PSIMAPP) for Landscape Analysis

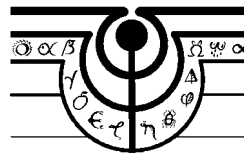
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This material is based upon work partially supported by (i) the National Science Foundation under Grant No. 0307010 and (ii) The United States Environmental Protection Agency under Grant No. CR-83059301. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the agencies.

[Presented at the 7th Annual International Conference on Digital Government Research]

Technical Report Number 2006-0529
TECHNICAL REPORTS AND REPRINTS SERIES
May 2006



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Progressively Segmented Image Modeling as Poly-Patterns (PSIMAPP) for Landscape Analysis

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ABSTRACT

Progressively Segmented Image Modeling As Poly-Patterns (PSIMAPP) provides pictorial parsimony and spatial structure for multi-scale landscape analysis based on image-structured multivariate signal data using geographic information systems (GIS). Modeling is accomplished by doubly segmenting images to obtain poly-patterns as approximating mosaics of segments at two levels of detail. The more coarsely aggregated A-level consists of 250 segments that are numbered in order of overall intensity and recorded as a byte binary map of segment numbers forming a MOSAIC (Mapping Ordered Segment Attribute Index Codes). The finer B-level of base segments has several thousand pattern partitions that are nested within A-level segments up to a maximum of 255 B parts in an A part. A second byte binary file serves as a binary index layer for mapping base segments. Several supplemental files of pattern properties are indexed and accessed by the pattern numbers. The patterns of the B-level base segments provide an image model, and the composite patterns of the A-level provide a multipurpose generalization. Together they constitute an IMAG (Image Model And Generalization).

Categories and Subject Descriptors

D. Software; E.1 Data structures; H.1 Information systems – models and principles; I.4 Image processing and computer vision; I.5 Pattern recognition; I.6 Simulation and modeling.

General Terms

Algorithms, Management, Measurement.

Keywords

Image modeling, Image compression, Landscapes, Geographic Information Systems, GIS, Pattern recognitions.

1. INTRODUCTION

Vast stores of environmentally relevant image data are obtained by modern remote sensors each day and entered into archives. Most of these images are substantially underused, and many are essentially unused. Landscape patterns contained in the images are subjectively detected by the eye of a human interpreter from spatial relations that are implicit in the data, but automated explicit extraction of such patterns is on the frontier of computer-intelligent information science.

Even though computerized geographic information systems (GIS) are becoming increasingly sophisticated at displaying image information, image analysis has remained largely a domain of special technical expertise. The large sizes of image data files

also constitute a deterrent to their routine use in GIS. There is need to systematize the extraction of information on environmental patterns from image data, and to make the encoding of pattern information more parsimonious to facilitate electronic storage, transmission, and incorporation into GIS data bases.

Conventional approaches to image analysis are also predicated on the assumption that recorded signals consist of spectral data. There is parallel need to analyze and extract landscape patterns from synoptic multivariate data on environmental indicators formulated from other kinds of signal sources. The toolkits for image analysis require augmentation to be more robust with respect to signal sources. The focus in PSIMAPP is on automated and computer-assisted extraction of landscape patterns from image-structured data on environmental indicators as well as from multi-spectral sensors.

2. RESEARCH

The PSIMAPP approach to image-structured environmental information begins with formalization of pattern constructs jointly in the signal domain and the spatial domain. These pattern constructs are then used to model image-structured data from multiple perspectives at several spatial scales and levels of detail. The pattern representations are more parsimonious than the parent image data, and are compatible with raster map representation used in geographic information systems. The results of the modeling can be displayed with software available to the public and downloadable without charge. However, these results are also structured for compatibility with the most widely used commercial GIS software facilities.

The modeling perspectives are encompassed symbolically as **I4C**, in which the 'I' alludes to images or indicators and the 4 Cs connote **contrast, content, context** and **change**. These are the kinds of generic concerns that patterns emerging from image-structured environmental data are most often used to address.

Innovative methods of image segmentation are central to the PSIMAPP approach. These methods of segmentation are highly computer intensive, but the resulting pattern models can be manipulated much more rapidly than the original multi-band images, and the pattern models support selective approximate restoration of conventional image structures.

The first stage of modeling extracts 250 contrasting segments from the image data in two phases. The choice of 250 is strategic with regard to encoding of a pattern map in single bytes of computer media. The second stage of modeling progressively

partitions the segments from the first stage using a specially developed pivoting polar partitioning algorithm to obtain base (B-level) patterns. The third stage reconciles first and second stages to obtain 250 aggregations of base-patterns as compound A-level patterns. The fourth stage orders the A-level patterns according to average signal intensity and encodes a byte binary A-level pattern map as a MOSAIC (Mapping Ordered Segment Attribute Index Codes) that can be displayed in the manner of a simple single-band image (see Figure 1). The B-level patterns are then mapped hierarchically in a second layer giving compound patterns, or **poly-patterns**.

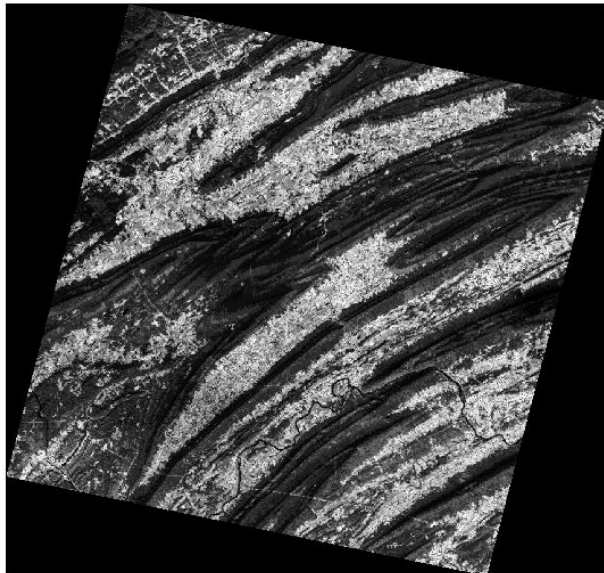


Figure 1. A-level pattern MOSAIC from ASTER satellite data for central Pennsylvania, September 2002.

Various attributes of the poly-patterns at both **A** and **B** levels are compiled and recorded in tabular form for subsequent pattern analysis. There are typically several thousand patterns of B-level base segments that comprise an image model, and the composite patterns of the A-level provide a multipurpose generalization. Together they constitute an IMAG (Image Model And Generalization).

Facilities are provided in the PSIMAPP software for automated contrast characterization of A-level patterns and auto-adaptive contrast control for color composite rendering of the patterns in pseudo-color image display mode. Color transfer tables are formulated to make pattern pictures mimic multi-band color composite image displays.

The B-level image model permits approximate restoration of band data for the original image, with options to select particular bands, areas, and enhancements. Residuals for the restoration can be mapped, and segmentation can be resumed to improve the

approximation as appropriate. Subtracting the restoration from the original image data provides a means of multivariate detrending for spatial statistics.

Content analysis is supported in multiple modes. Computer-assisted interpretive identification provides a synergistic coupling of human pattern perception and computer coding. Algorithmic assignment of thematic classes is enabled by an adaptive assignment advisor that produces thematic transform tables by a blend of supervised and unsupervised modes. Additionally, the B-level model permits approximated multi-band restoration for classification with conventional image software systems.

Detection and analysis of landscape change has been a particular focus and major motivation for PSIMAPP image modeling. The pattern-based parallel to change vector analysis provides the benefits of a smoothing filter to improve spatial coherence of change maps. Pattern models provide for an innovatively different method of change detection that is not available for actual image data. In this mode, patterns are spatially matched between dates. Patterns also allow integrated analysis of change across multiple occasions of image acquisition.

Multi-scale analysis of landscape structure can be conducted via pattern profiles for blocks of pixels spanning the scales of interest. Pattern progressions can be obtained by partial ordering and range ranking that reveal consistencies and inconsistencies among signal structures of segments.

3. ACKNOWLEDGMENTS

This approach owes its origins to multiple sponsors over several years and projects including NASA, NSF, EPA, USGS Biological Resources Division, the National Geospatial Intelligence Agency, the Penn State University Agricultural Experiment Station, the Penn State Institutes of Environment, and KUSTEM University in Malaysia. See also www.orssir.psu.edu web pages.

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