Object-Based Image Analysis Utilizing Image Segmentation Hierarchies

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OBIA Motivation:

- Pixel-based analysis techniques are generally not effective in extracting information content from high spatial resolution remotely sensed imagery data. The general consensus is that region or object-based analysis should be more effective.

Our Approach:

i. Utilize RHSEG to produce a hierarchical segmentation of the image or image-like data.

ii(a). Problem specific: Devise approaches for analyzing the RHSEG segmentation hierarchies tailored to a specific application.

ii(b). General: Utilize the Subdue graph-based knowledge-discovery system to extract and/or discover relevant information from the segmentation hierarchies produced by RHSEG.

RHSEG Background: HSEG

- The Hierarchical Segmentation (HSEG) algorithm produces a hierarchical set of segmentations from image or image-like data.

What is a Hierarchical Set of Segmentations?

It is a set of image segmentations that

i. consist of segmentations at different levels of detail, in which
ii. the coarser segmentations can be produced from merges of regions from the finer segmentations, and
iii. the region boundaries are maintained at the full image spatial resolution.

Advantages of Image Segmentation and Segmentation Hierarchies:

- Image Analysis is transformed from pixel-based analysis into region-based or object-based analysis.
- A hierarchy of segmentations allows dynamic selection of the appropriate level of segmentation detail for each object of interest.
- Behavior of regions up and down the segmentation hierarchy may also provide analysis clues.

Hierarchical Segmentation (HSEG):

HSEG is a hybrid of Hierarchical Step-Wise Optimization* region growing together with a form of spectral clustering – controlled by a *spclust_wght* parameter.

* J. M. Beaulieu and M. Goldberg, “Hierarchy in picture segmentation: A stepwise optimal approach,”*IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 11, no. 2, pp. 150-163, 1989.

RHSEG:
Recursive Hierarchical Segmentation

A recursive approximation of HSEG, called RHSEG, is much more computationally efficient (especially for *spclust_wght* > 0.0).

- RHSEG recursively subdivides the image data and then recombines the results such that the number of regions handled at any point in the program is restrained.

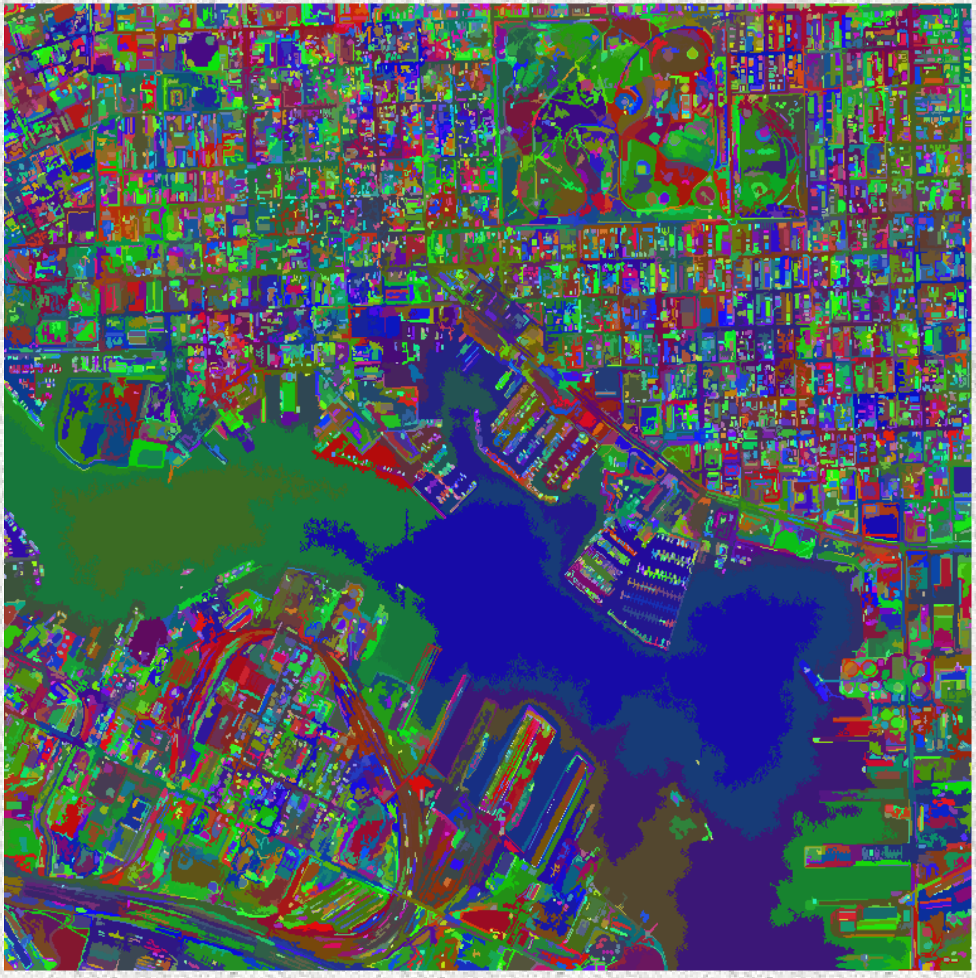
- The recombination step requires special blending code to avoid processing window artifacts.

Parallel RHSEG:

- Recursive HSEG (RHSEG) facilitates a highly efficient parallel implementation – a full Landsat TM scene (6500x6500 by 6 bands) can be processed in two to eight minutes with 256 2.1 GHz CPUs (Thunderhead Beowulf Cluster).

HSWO Segmentation:

A true color rendition of a 768x768 pixel section of Ikonos data from the Patterson Park/Inner Harbor area of Baltimore, MD.



HSWO Segmentation with 7415 region objects. (global dissimilarity = 0.346)

RHSEG Segmentation:

A true color rendition of a 768x768 pixel section of Ikonos data from the Patterson Park/Inner Harbor area of Baltimore, MD.

RHSEG Segmentation with 11 region classes and 38,773 region objects. (global dissimilarity = 0.345)

Subdue'ing RHSEG: The Marriage of Graph Based Knowledge Discovery (Subdue) with Image Segmentation Hierarchies (from RHSEG) for Data Analysis, Data Mining and Knowledge Discovery:

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Co-I: Diane J. Cook, School of Elect. Eng. & Comp. Science, Washington State University, Pullman, WA, USA

Objective: To explore methods for effectively combine a graph-based knowledge discovery approach, called Subdue, with a hierarchical segmentation approach, call RHSEG, for analysis of image or image-like data.

Goal: It is expected that RHSEG will abstract the image pixel data into region objects from which Subdue will be able to discover or identify meaningful patterns and relationships.

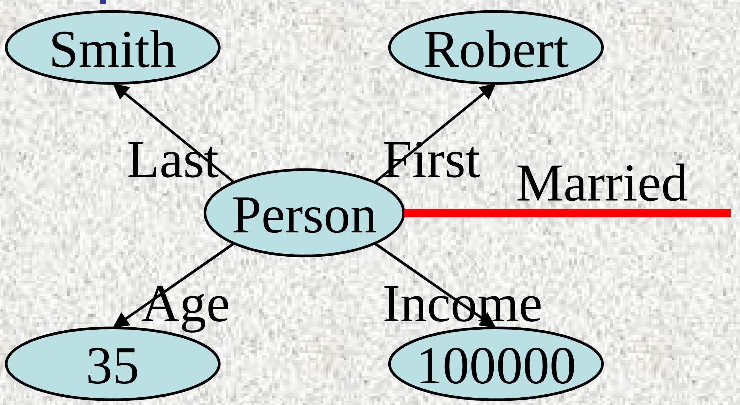
Impact: A successful combination of RHSEG and Subdue will lead to a more effective data analysis, data mining and knowledge discovery for NASA (and other) data.

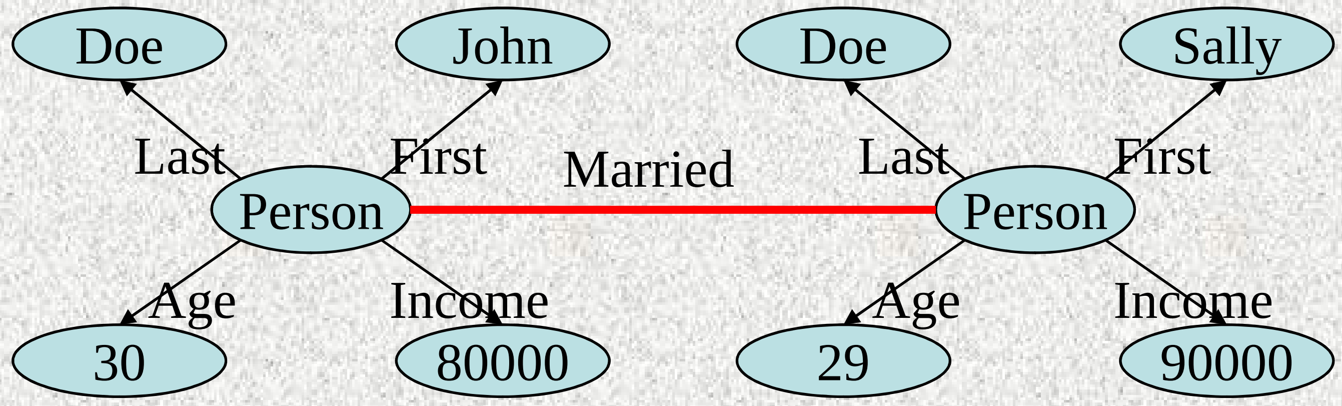
Status: One year seed project, funded by the NASA AISR program was completed Sept. 2008.

Follow-on proposal was submitted to the NASA AISR program in August 2008 – a two year project was proposed with an April 2009 start date – NOT SELECTED FOR FUNDING.

Graph-based Relational Learning

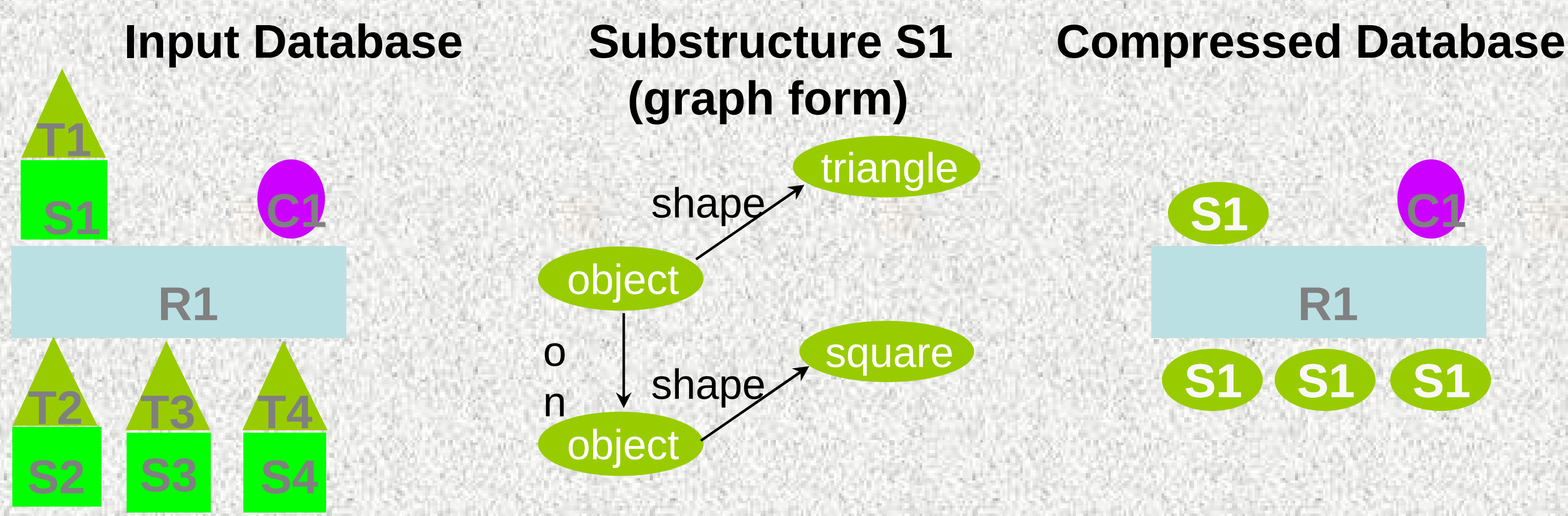
- Most data mining algorithms deal with linear attribute-value data
- Need to represent and learn relationships between attributes
- Finding patterns in graph(s)
  - Discovery
  - Clustering
  - Supervised learning





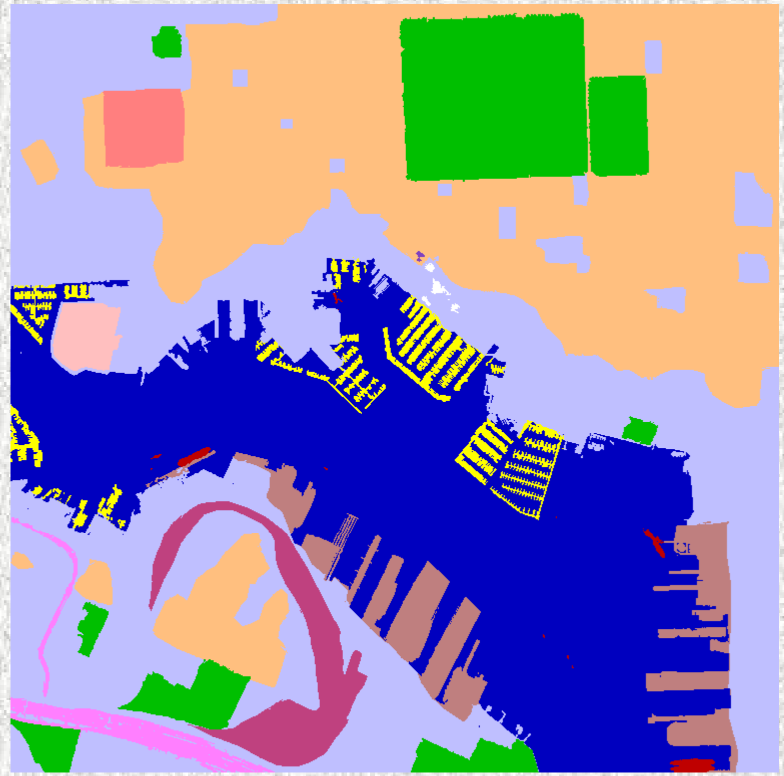
Graph Representation

- Input is a labeled (vertices and edges) directed graph
- A substructure is a connected subgraph
- An instance of a substructure is an isomorphic subgraph of the input graph
- Input graph compressed by replacing instances with a vertex representing the substructure



RHSEG/Subdue combination: First Steps

A true color rendition of a 768x768 pixel section of Ikonos data from the Patterson Park area of Baltimore, MD.



Goal for RHSEG/Subdue combination: A labeling in terms of generalized labels.

Color Key: Marinas, Clouds (white), Housing Project, I-95 & Key Hwy, Commercial Development, Dredge Fill, Docks, Residential, Cloud Shadows, Rail Yard, Baltimore Harbor, Parks, and Other.

RHSEG/Subdue combination: First Steps

A true color rendition of a 768x768 pixel section of Ikonos data from the Patterson Park/Inner Harbor area of Baltimore, MD.

RHSEG Segmentation with 11 region classes and 38,773 region objects.

Graph Coding Example

12	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9
8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	1
8	8	8	8	8	8	8	8	8	8	8	8	8	9	1	8
8	8	8	8	8	8	2	2	8	8	8	8	11	1	9	8
3	3	8	8	8	8	2	8	8	8	8	8	8	8	8	8
3	8	8	8	8	8	8	8	8	10	10	8	8	8	8	8
8	8	8	8	8	8	8	13	8	8	8	10	8	8	8	8
8	8	8	8	8	8	8	8	8	8	10	10	8	8	8	8
4	8	8	8	8	8	8	8	8	5	10	8	8	8	8	8
8	8	8	8	8	8	8	8	5	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8	8	6	6	8	6	6
8	8	8	8	8	8	8	8	8	8	8	6	6	6	8	8
8	8	8	8	8	8	8	8	8	8	8	6	6	6	8	8
8	8	8	8	8	8	8	8	8	8	8	6	6	8	8	8
8	8	8	8	8	8	8	8	7	8	8	8	8	8	8	8
8	8	8	8	8	8	8	7	7	8	8	8	8	8	14	14

Color coded map of a 16x16 pixel section of the RHSEG segmentation of the northeast corner of Patterson Park.

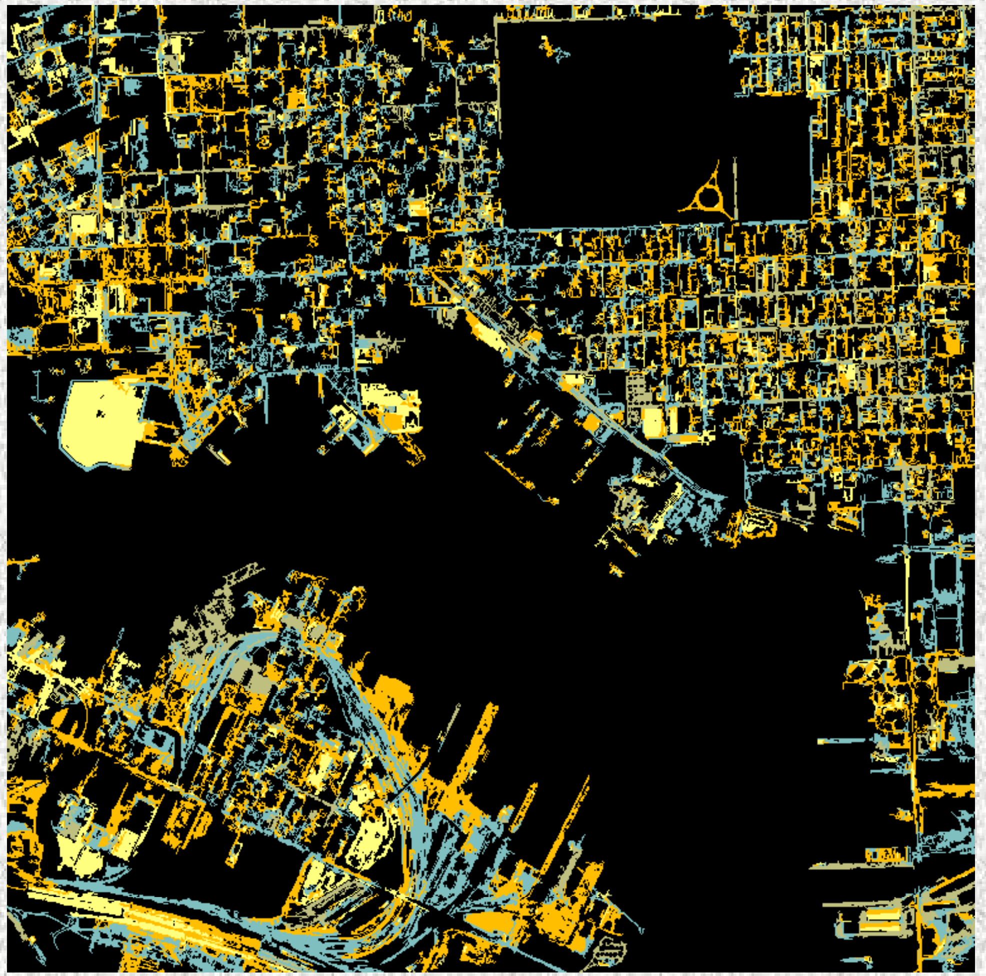
Region Class	Color
1	
2	
3	
4	
5	

Graph vertices and edges:

(v "region object" "region class")
v 1 3, v 2 1, v 3 1,
v 4 1, v 5 1, v 6 1,
v 7 1, v 8 2, v 9 4,
V 10 4, v 11 1, v 12 5,
v 13 5, v 14 1

(u "1st region" "2nd region" "relationship")
u 1 8 link, u 1 9 link,
u 1 11 link, u 2 8 link,
u 3 8 link, u 4 8 link,
u 5 8 link, u 5 10 link,
u 6 8 link, u 7 8 link,
u 8 9 link, u 8 10 link,
u 8 11 link, u 8 12 link,
u 8 13 link, u 8 14 link,
u 9 11 link

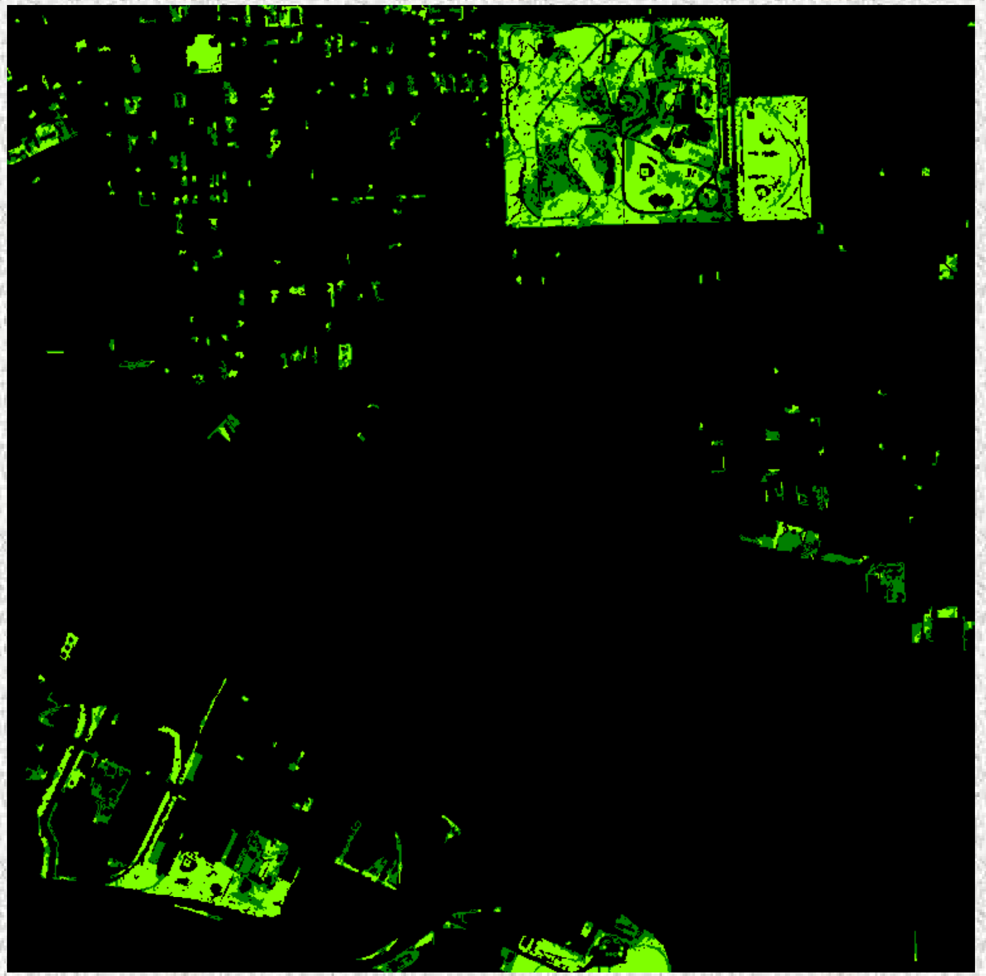
RHSEG/Subdue combination



Subdue Subgraph Instance 1: 4-5-3 (-9)

RHSEG Segmentation Result

RHSEG/Subdue combination

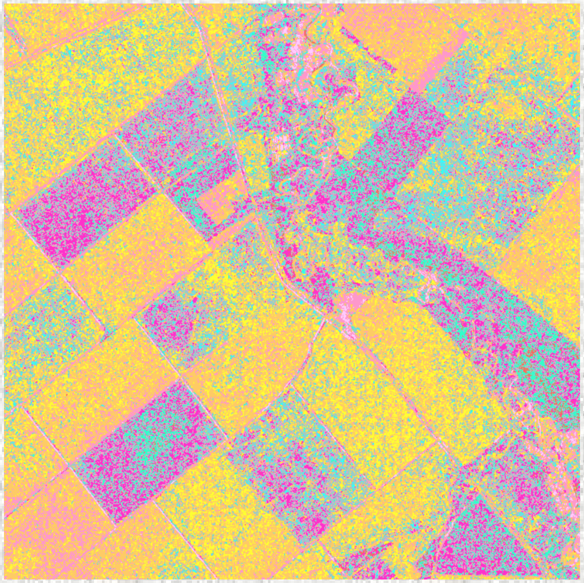


Subdue Subgraph Instance 8: 6-8

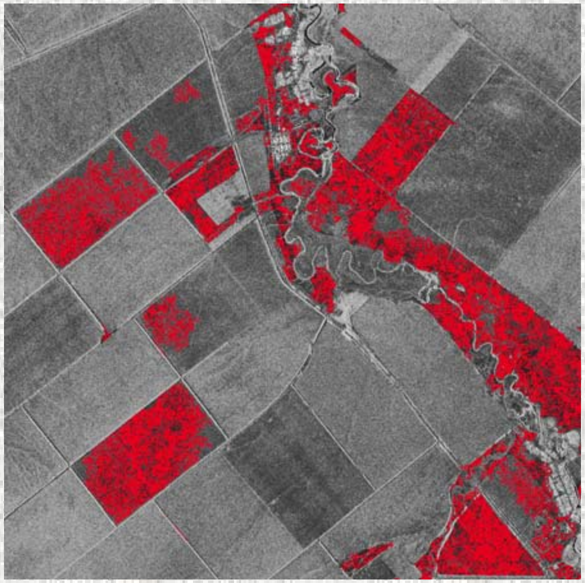
RHSEG Segmentation Result

RHSEG/Subdue combination: TerraSAR-X data

A section of TerraSAR-X imagery data.



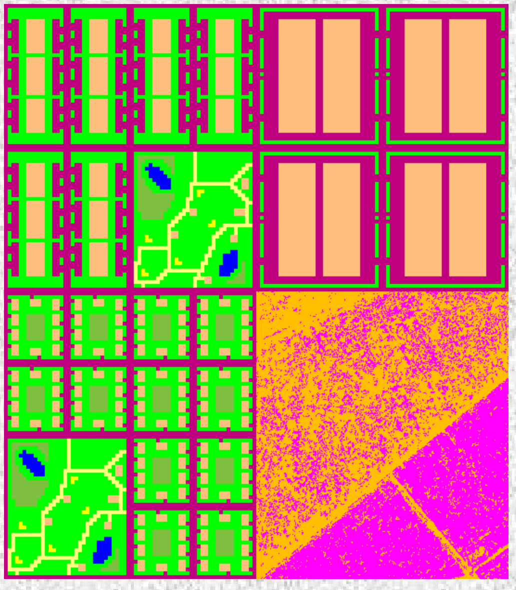
Ten region class segmentation produced by RHSEG.



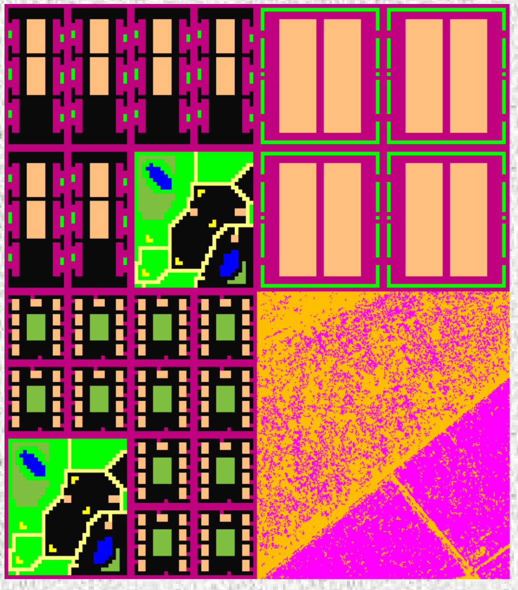
Areas covered by instances of the sixth most significant subgraph discovered by Subdue.

Simulated Segmentation/ Subdue combination:

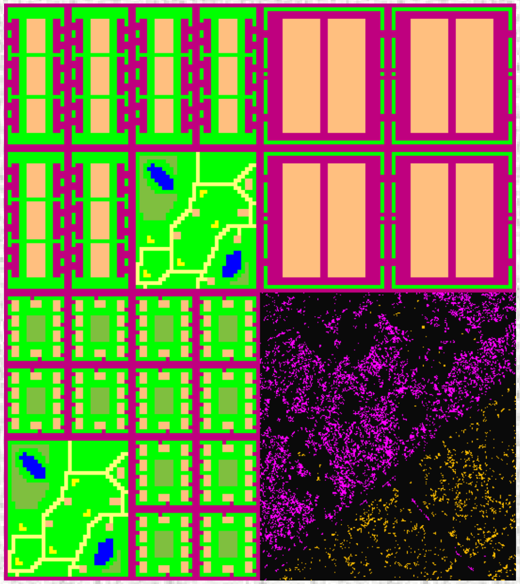
Simulated Image Segmentaton:



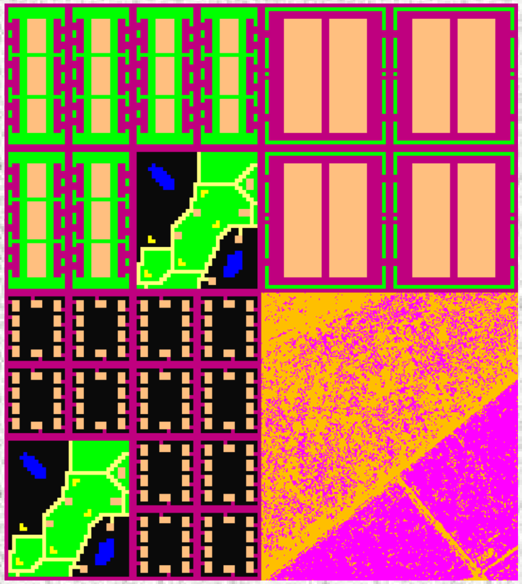
Most Significant Sub-Graph from Subdue:



Second Most Significant Sub-Graph from Subdue:

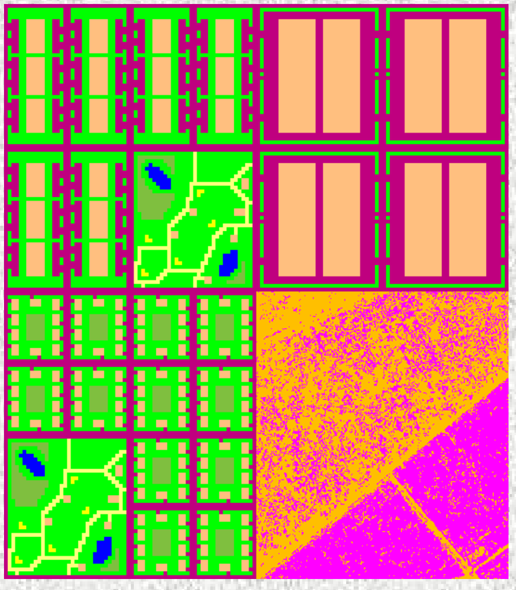


Third Most Significant Sub-Graph from Subdue:

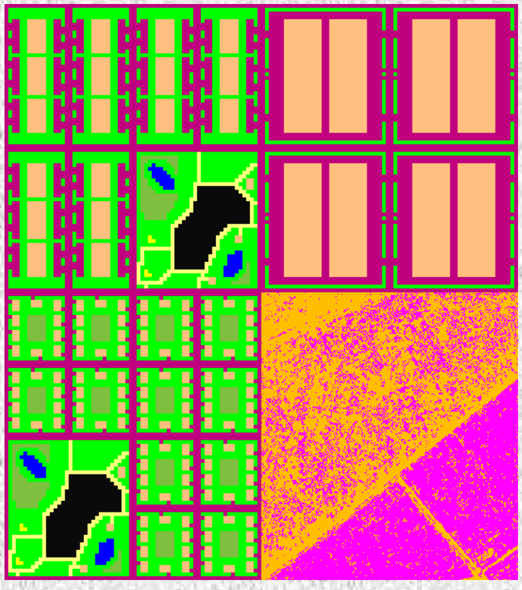


Simulated Segmentation/ Subdue combination:

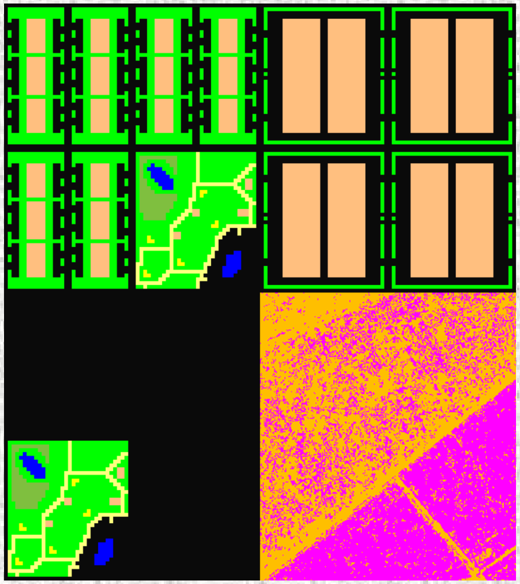
Simulated Image Segmentaton:



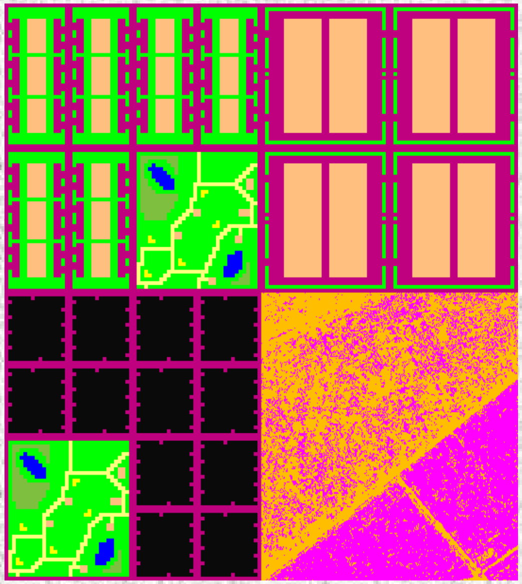
Most Significant Sub-Graph from Subdue with at least five vertices:



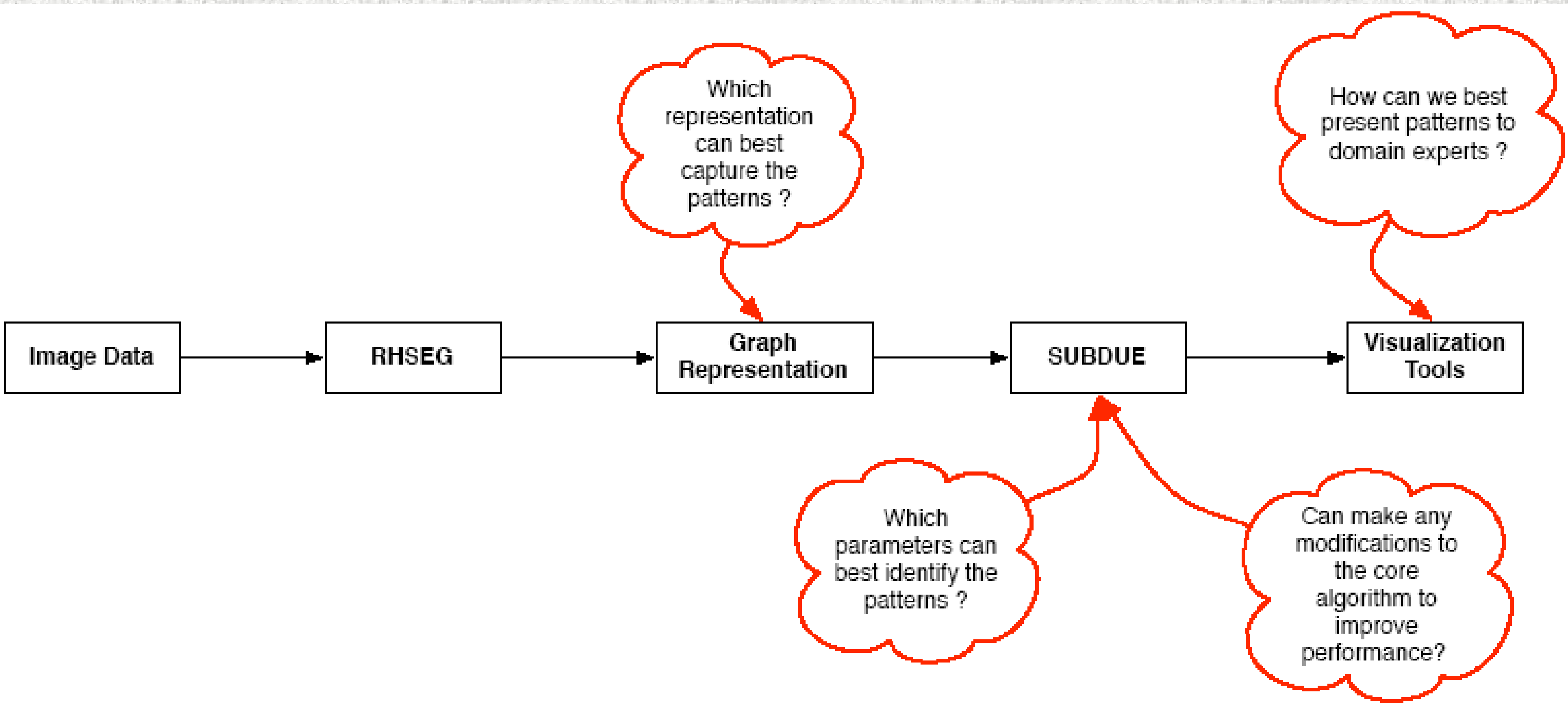
Second Most Significant Sub-Graph from Subdue with at least five vertices:



Third Most Significant Sub-Graph from Subdue with at least five vertices:



Key Issues in Integrating RHSEG and SUBDUE



Proposed New Work:

Tasks listed in new proposal to NASA's Applied Information Systems Research program:

- Provide Subdue with rudimentary region size information by determining region subclasses based region object sizes (through histogramming).

- Enable Subdue to utilize RHSEG segmentation hierarchy information by utilizing the approximate matching of Subdue and introducing a region class "closeness" matrix based on closeness in the hierarchical segmentation structure.

- Improve Subdue processing throughput by assuming planer graph input. Graph theory indicates that segmentations of two dimensional images can always be represented as planer graphs. This will speed up the Subdue analysis dramatically.

- Explore general approaches for enabling Subdue to utilize region object size and region object neighbor relationship information. This would utilize recent and current work by Selim Aksoy.

Though not selected for AISR funding, this work will continue in FY2010 through NASA GSFC IRAD funding.

OBIA for Data Analysis, Data Mining and Knowledge Discovery

PI: James C. Tilton/Code 606.3

Description and Objectives:

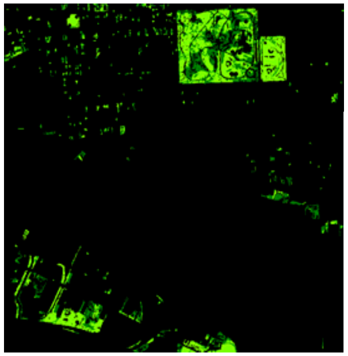
Key challenge(s)/Innovation: Moving from pixel-based to object-based image analysis (OBIA) through the application of Recursive Hierarchical Segmentation (RHSEG) Software to OBIA .

Two-pronged approach:

i. Development of generalized techniques for OBIA.

ii. Development of collaborative relationships with space and Earth scientists in order to form a clear understanding of image analysis needs that can benefit from OBIA.

RHSEG Segmentation



Subdue Subgraph

Analysis of Ikonos image of Baltimore, MD

Approach:

- Follow-up on previous work in utilizing a graph-based knowledge discovery system, called Subdue, to find meaningful patterns in the hierarchical image segmentations produced by RHSEG.
- Work with space and Earth scientists in developing specific, perhaps ad hoc, OBIA approaches tailored to their image analysis needs.

Collaborators:

- Diane J. Cook (Subdue developer), Wash. State U.
- Selim Aksoy, Bilkent University, Ankara, Turkey

Milestones and Schedule:

- Jan. 2010- Submit definitive RHSEG paper to a refereed journal
- TBD* – Submit general OBIA research proposal
- TBD* - Submit research proposal for specific application of OBIA to a space or Earth science application
- Sep. 2010 –OBIA demo for MODIS Snow/Ice proj.
- Sep. 2010 – OBIA demo for Space Arch. proj.

** Date depends on ROSES 2010 deadlines*

Application / Mission:

- Cross cutting mission to improve image data analysis capabilities for space and Earth science applications.

This work was supported by NASA's Applied Information Systems Research (AISR) program.

For more information of RHSEG and Subdue, and instructions on obtaining a demonstration version of RHSEG, contact:

James.C.Tilton@nasa.gov

The Core HSEG Open Source Package is available from:

http://opensource.gsfc.nasa.gov