Introduction to Object-Based Image Analysis (OBIA) with eCognition

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What do you see?
Human Cognition

- From the Latin word Cognoscere meaning “to know", "to conceptualize" or "to recognize“
- The human faculty for processing information, creating categories, applying knowledge, and changing preferences.
- Cognitive processes can be conscious or unconscious.
Human Cognition and Image Interpretation
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How humans see and classify objects

- Sense organs gather and sort raw data
  - Rods and Cones: Brightness and Color
- Brain processes, filters, and classifies data and presents our conscious mind with information.
- If our consciousness were presented with everything that our senses collected we would be inundated and unable to function.
- Information presented to our consciousness is Qualitative.
- Our brains work from Complexity to Abstraction
Creating Categories: Land-use and Land-cover

- What our conscious mind sees is determined by the categories we have created.
- We tend to find what we are looking for.
- Forests can be alpine or bottomland, wild or managed, old-growth or regenerated, or the back 40.
- Trees can be a forest, tree farm, orchard, wind-break, arboretum, or your back yard.
- A tree can be coniferous, deciduous, ornamental, native, invasive, or your favorite shade tree.
From Complexity to Abstraction

• When we look at an aerial photograph, or the world around us, we are presented with great complexity.
• We are naturally wired, for our very survival, to make abstractions from the images we see around us.
• We are also conditioned by our upbringing, our surroundings, and even by our training as Earth remote sensors to make certain kinds of abstractions.
Qualitative Concepts: Difficult for Computers
How computers “see” and “classify” objects

- Computers “see” digits and process quantities.
- Computers require rules (programs) to process those digits.
- These rules, compared to human cognition, are “relatively” simplistic and deal with specific quantities employing mathematical or logical operations.
- The level of categorization necessary for image classification, compared to that of the human mind, is infinitely more abstract and infinitely less complex.
3 Band (RGB) Color Composites

Grey Level Values or Digital Numbers (DN)

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|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 68| 77| 64| 71| 79| 64| 56 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 62| 58| 57| 63| 66| 68 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 56| 49| 49| 48 |45| 55| 68 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 58| 67| 66(60)| 66| 50| 62 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 55| 68| 61 |57| 56| 57| 47 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 63| 59| 47 |51| 44| 45| 63 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 45| 67 |69 |54| 47| 45| 59 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 62| 70| 70 |71| 67| 48 |48 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 59| 66| 52 |53| 49| 52| 47 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 50| 43 |43 |38| 41| 51| 72 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 41| 38 |35| 35| 43| 49| 67 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 58| 62 |44 |42| 49| 47| 47 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 45| 47 |36 |36| 45| 43| 53 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 44| 53 |49 |47| 41| 45| 49 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 27| 24 |26| 30| 32| 30| 23 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 30| 24 |21| 27| 33| 35| 23 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 27| 21 |21| 25| 27| 33| 27 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 23| 21 |21(21)| 29| 27| 23 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 24| 28 |21| 28| 36| 28| 21 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 24| 24 |24| 28| 33| 33| 24 |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 27| 28 |23| 22| 21| 21| 33 |   |   |   |   |   |   |   |   |   |   |   |   |   |
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Home of the Ivory-Billed Woodpecker
Pixel Possibilities

By determining the various color combinations (digital signatures) for individual categories, e.g. forest, pasture, urban, etc., it is possible to classify an image based solely on pixel values.

New Subdivision in Fayetteville, AR

QuickBird Satellite Image: 2004
(Copywrite: DigitalGlobe, Inc.)

Resulting 3 Category LULC Map
(Produced at UA-CAST: 2004)
So, what is OBIA?

An approach to image processing which employs

- An attempt to make image processing more like the human cognitive process.
- The partitioning remote sensing (RS) imagery into meaningful image-objects (segments) based on spatial, spectral and temporal homogeneity.
- The attribution of image-objects based on the parent RS imagery, as well as other data sources.
- The classification of image-objects using rules which analyze object attributes, relationships with other objects within the image, or relationships with external objects (Themes).
History of OBIA

- Cognitive Psychology and Sensory Studies
- Gestalt Psychology and its applications in the arts
- Computer “Vision” and Medical Imaging
- An ever-growing sophistication of user needs and expectations regarding GIS products
- Recognition of limitations with pixel-based image approaches (i.e., that pixels are not true geographical objects.)
- Early approaches to pixel analysis in RS: texture, sub-pixel analysis, etc.
- Attempts to blend the vector and raster world in GIS
- Increasingly affordable and powerful computing tools
- Maturing of object-oriented programming
- Recognition of the need for multi-scale approaches in the monitoring, modeling and management of our environment, for which object-based methods are especially suited.
- Here we are TODAY!
The Complexity to Abstraction Process for OBIA

- Creating and Employing a “Class Hierarchy”
- Delineating meaningful objects (Segmentation)
- Quantifying object characteristics (Attribution)
- Selecting relevant attributes for categories and categorization
- Reshaping Objects
  - Merging similar small, contiguous objects into bigger objects
  - Growing objects by attribute thresholds
  - Breaking big objects into smaller objects
  - Shrinking objects by attribute thresholds
- Assigning objects to a category
- Filtering noise
- Exporting Objects to GIS for further analysis or continued OBIA
Image Segmentation (Defined)

- Commonly, the term segmentation means subdividing an image, or entities within an image, into smaller, meaningful partitions.

- Yet… Segmentation is any operation that creates new image objects or alters the morphology of existing image objects according to specific spatial, spectral, or textural criteria.

- This means that segmentation can be a subdividing operation, a merging operation, or a reshaping operation.
Segmentation
Image Objects

- Well defined segments have “objective” meaning.
- In this example objects, correspond to a desired subset of the overall image: skin, hair, eyes, smile, background, shadow, etc.
Delineating Objects: Top-Down or Bottom Up

• Top-down segmentation means cutting big objects into smaller objects. For example, cutting the entire image of Mona Lisa into smaller components like skin, hair, dress, etc. Those component objects could then be broken down further... Even divided into individual pixels.

• Bottom-up segmentation means assembling small objects to create a larger objects. For example taking all individual pixels and then constructing the individual components (eyes, hair, background, etc.) that make up the Mona Lisa image.

• Hybrid Approach: Nothing prevents the user from combining Top Down and Bottom Up Approaches.
Segmentation: Chessboard

- Top Down
- The simplest segmentation algorithm
- Image cut into equally-sized, square image objects.
- No regard for spectral or spatial information in process
- Yet, attributes for the square segments are stored for further analysis
- Very Fast Algorithm
- Good for First Pass Scale/Resolution Reduction
- First Pass Segmentation followed by Multi-resolution Segmentation
Segmentation: Quadtree

- Top Down
- Similar to Chessboard.
- Creates Squares of differing sizes based on spectral and spatial homogeneity.
- Attributes for the square segments are stored for further analysis.
- Very Fast Algorithm
- Excellent First Pass Segmentation
Quadtree
Segmentation: Multi-Resolution

- Bottom Up
- Consecutively merges pixels based on spatial and spectral homogeneity.
- Size of resulting segments (based on scale parameter).
- Shape of resulting segments based on shape/color parameters.
- Somewhat slow, memory resource-intensive algorithm.
- Yields good image abstraction.
- Can create slivers and noise.
- Often used as a secondary segmentation process after Chessboard or Quadtree.
Multi-Resolution
Image Segmentation Components

- Defining Scale… Forest or Trees?
- Spectral Homogeneity
- Shape Homogeneity
- Incorporating existing data: Themes
Scale

Scale = 30  OBJECTS = Bright Skin, Shadowed Skin, Eye Components, Mouth, Curly Hair, Straight Hair, etc.

Scale = 500  OBJECTS = Face, Hair, Background
### Segmentation Homogeneity: Spatial and Spectral

- **Spatial Homogeneity**: A high Spatial Homogeneity setting results in more spatially homogenous objects; i.e. all resulting objects will be roughly the same size and shape.

- **Spectral Homogeneity**: A high Spectral Homogeneity setting results in more spectrally homogenous objects; i.e. all resulting objects will be similar in their level of spectral homogeneity.

- **NOTE**: These two settings have an inverse relationship.
Theme Example
Class Hierarchy

- A method for systematically categorizing image objects.
- Useful for breaking out land-use type objects from land-cover objects.
- Often used in OBIA as temporary classes. The objects in those temporary classes will either be assembled to form larger objects or broken apart into various components in subsequent processing routines.
  - For example, a temporary category called “Dark Objects” may later be split into 2 categories: “Shadow” and “Clear Water.”
Class Hierarchical Strategies

- **Bottom Up Approach:** Categories such as mouth, nose, eyes, etc. can be combined to create “Face.”
- **Top Down Approach:** A category called “Face” could be broken down into components called mouth, nose, eyes, etc.
Objects Have Characteristics

• Color: Mean “color” values for each object in each band
• Size: How big or small is the object?
• Shape: Squareness, Roundness, Length/Width Ratio, etc.
• Texture: Contrast, Homogeneity, Dissimilarity
• Context: How does the object relate to its neighbors?
• The big picture: How individual object characteristics interrelate to the entire image. Relative Location, Sub Objects, Super Objects.
Example
Spectral Characteristics

Light Blue →

- Red
- Tan
- Green
- Blue
- Yellow
- Tan
- Blue
Geometrical Characteristics

Big Square
Textural Characteristics: Homogeneity
Relationships to Image and Other Objects

- Nearest Neighbor
- Nearest Blue Object
- Nearest Low H Object
- Center
- Only Green Object
- Surrounded by Red

Surrounds all other Objects
Predominate Land-use?
Segments: Pixels to Vector Objects
Object Characteristics (Attributes)

Cropland: Bare Soil
Object Characteristics (Attributes)

Cropland: Crop in Field
Object Characteristics (Attributes)

Not Cropland: Curtledge
Objects can be classified based on their attributes
Rule-building Strategies

- Classify Objects from Simple to Complex
  - Homogenous to Heterogeneous
  - Large to Small
  - Simple Shapes to Complex Shapes
Rule-set Demonstration

- Segmentation (Quadtree and Multi-Resolution Hybrid)
- Class Hierarchy
- Merging Objects
- Growing Objects
- Splitting Objects
- Classification: Assign, and Manual Adjustments
OBIA Exercise with eCognition

Segmentation, Exploration, Object Shaping, Class Hierarchy, and Classification

DOWNLOAD:
http://tinyurl.com/368ckm2