Geo-objects, Image-objects and Their Relations: A Geospatial Cognition Perspective

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KEYWORDS: geo-objects, image-objects, object-based image analysis, image-segments

Object-based image analysis (OBIA), or geographic object-based image analysis (GEOBIA), is a new branch of Geographical Information Science. Geo-objects and image-objects are predominant elements in OBIA. A pioneering approach clarified the two concepts. However, the relations between geo-objects and image-objects become dubious as two types of image-objects are proposed: initial and meaningful. In this paper, the author sets forth the principal views for these two concepts and their relations with respect to geospatial cognition.

Geo-objects are developed in a course of geospatial cognition and are given semantic or nominal definitions for specific geospatial units providing that the earth surface can be divided into a series of geospatial units. Geo-objects are different due to their different impacts on human's activities. Geo-objects are cognized through a course beginning from: (1) cognition activities in human's daily life; and (2) surveying and mapping; to (3) remote sensing analysis with personal experience. The course indicates a methodological shift of cognition activates from qualitative to quantitative means and from manual practice to computer aided delineation. Geo-objects are modeled with respect to forms and processes. Geometrical models are digital forms of geo-object models for the geospatial extent and characteristic of their own inherent scales; i.e. the minimum grain size and the maximum extent for measurements. The geometrical model of geo-objects is normally of three-dimensional and divided into point, line/polyline, polygon, or polyhedron model in the 0-, 1-, 2-, and 3-dimensional framework, respectively. Whatever a geo-object taking a kind of geometrical models or not is dependent on its geospatial scale; i.e. level of details for anthropocentric focus. In most cases, point models are available for geospatial sampling; line or polygon models are useful for study on landscape ecology and regional planning; and polyhedron models are used for the study of digital city. In addition, a geo-object can be composed of one or more sub-objects. Few geo-objects constitute a super-object. Sub-objects, geo-objects, and super-objects have inheritance relations in properties and make up a nested hierarchical landscape system. A geo-object is set a group of features concerning spectrum, texture, shape, size, and contextual properties in remote sensing image. The geometrical models are in turn used for recognizing and modeling other unknown geo-objects on the earth surface.

Image-objects are constructed from remotely sensed images. Image-objects are described with respect to their features on spectrum, texture, shape, sizes, and spatial resolution.

These features are then transformed to rule sets for feature extraction or image classification with OBIA paradigm. The grain size or spatial resolution of image-objects depends on the remote sensing images of which they made. Most civilian remote sensing images nowadays have spatial resolution from few decimeters to few kilometers. Image objects are extracted by means of image segmentation. However, each dataset of image segmentation does not necessary belong to certain image-objects. The general resulting dataset of image segmentation is referred to image-segments. Image-segments are characteristic of intra-segment homogeneous, inter-segment heterogeneous and non-overlapping regions in remotely sensed images. Image-segment dataset is constructed using one of parameter settings for image segmentation. In the dataset, all image-segments cover the entire area of image coherently and are not overlapped each other. Conducting image segmentation with a series of parameter settings, the resulting datasets make up a data cube. The size and shape of image-segments depend on the data source of remote sensing images and algorithms and parameter settings of image segmentation. The minimum size of image-segments can be a pixel in images; the maximum size can be the whole extent of images. Although image segmentation concerns only areal features, image-segments can be cells, strings of cells, and regions with cells. The basic unit of an image-segment is a cell or a pixel in remotely sensed images with a limited geospatial extent, depending on remote sensor and its loading platform. In 2-D vector/raster framework, a single cell represents a point; a string of cells represents a line or polyline with regard to the criterion of 4-neighbor or 8-neighbor connectivity; and a group of cells at a plane represents a polygon or region with spatial continuity to maintain inner connectives. Whether an image-segment corresponding to a geometrical model of a geo-object or not depends on a geometrical model dropping into an image-segment.

Both geometrical models of geo-objects and image-segments bridge the gap between geo-objects and image-objects. Given geometrical models with finer grid resolution than image-segments, the author suggests two areal-overlap-based indexes, overlap-to-geometrical model ratio and overlap-to-segment ratio, to describe eight geometric relations between a geometrical model of a geo-object and an image-segment. They are:

(1) A geometrical model not overlapping any part of an image-segment;
(2) Minority of a geometrical model overlaying with minority of an image-segment;
(3) Majority of a geometrical model overlaying with minority of an image-segment;
(4) Minority of a geometrical model overlaying with majority of an image-segment;
(5) Majority of a geometrical model overlaying with majority of an image-segment;
(6) The extent of a geometrical model larger than and containing an image-segment;
(7) The extent of a geometrical model smaller than and being inside an image-segment;
(8) A geometrical model and an image-segment overlapping each other with the same size.

All these eight cases are composited into a quadrant diagram with these two areal ratios as axes and show a simple diagram.

In case of 0-D geospatial framework, the concerned geometrical model is point, and the basic unit of image-segments is cell of image data, and the relations between both are simplified into two: i.e., relation (1) and relation (8). In case of 1-D framework, the geometrical model means line or polyline and image-segment means a string of cells. Each cell connecting to one or two neighbor cells with the 4-neighbor or 8-neighbor connection criterion. Relations from (1) to (8) are all possible. In case of 2-D framework, a geometrical model means a region or a polygon and image-segment means a set of cells with relation of neighboring each other more than 2. Relations from (1) to (8) are all possible. The eight relations are also suitable in case of 3-D framework although the method for 3-D image is developing.

An image-object is referred to be an image-segment only if it is constructed to meet the relation (8) for segment data cube at all possible presetting of image segmentation. However, it is less possible. In practice, a candidate image-segment is regarded as an image-object provided the optimal result with relation (5) in a data cube of image-segments. The reasons are from both sides. Many boundaries for geo-objects are not always obviously and become a common sense in practice, especially the natural boundary. The discrepancy exists often because of personal judgments. On the other hand, image-segments are created with respect to the algorithms and parameters of image segmentation upon which remote sensing images are segmented. A great amount of algorithms developed in past decades concerns to image characteristics of grey level or texture, edges, region, or the combination. Changes in parameter of image segmentation induce also different dataset of image-segments. In a course of multi-scale segmentation, on the other hand, secondary and following segmentation necessary are conducted based on previous segmentation or not. Whether an image-object containing other smaller image-objects or not depends on the presetting procedures of image segmentation.

The fundamental reason for the gap between geo-objects and image-objects is the difference of human's cognitions on geospatial forms and processes and the lack of powerful algorithm of image segmentation.