SAND2009-1633P

Sandia National Laboratories

Operated for the U.S. Department of Energy by

Sandia Corporation

Albuquerque, New Mexico 87185-1316

date: March 10, 2009

to: File

from: Carl Diegert

subject: Notes on a gap in advancing geospatial image processing methods for NA-22

To advance image-analysis technology for NA-22, we are interested not just in geospatial data [1], but in answering questions about geospatial data, and in automatic processing that can at least assist humans in noticing something novel in a large, spatial dataset. Widely implemented standards [2] already provide for systems when semantics are simple. For example, COTS implementations routinely answer *find all the pizza retailers within a mile of my current location.* Defining more comprehensive geospatial ontology is a current incubator activity of the W3C. Use cases for this W3C and related work include at least some of the geometric semantics that could advance image-analysis for the verification and attribution challenges under NA-22. For example, one use case is to query for things related to recycling programs that are *at a given spatial scale* [3].

This note considers finding evidence to help resolve a semantic query from the information in an image, where the picture elements (pixels) of the image are regularly-sampled, implicitly-geocoded radiance values. One popular approach, often called object-based image analysis, OBIA [4], is to begin by *segmenting* the image pixels into sets of related pixels called segments. A commercial implementation [5] allows you to construct segments by choosing from several fundamentally different algorithmic definitions of how pixels are judged to be related, and then to adjust a handful of parameters that further define the algorithm. What this vendor calls semantic meaning is anything that is correlated with the statistical (or hand-constructed rule-based) classification of segments into a hierarchy of classes [6].

While more development of OBIA methods should benefit NA-22 with applicable image analysis methods, there are other approaches. We suggest that what we could call *computational geometry image analysis*, CGIA, would begin with the traditional abstractions of computational geometry (points, segments, and triangles), and define maps to the image pixels much different than the ridged segmentation imposed in OBIA. As an example, consider a study where semantics of a housing subdivision's density is based on a Delaunay triangulation of the centers of the houses comprising the neighborhood. Constructing this two-dimensional triangulation depends on these abstractions through two geometric traits (orientation of point sets and point within oriented circle predicate). Now suppose that the semantics of neighborhood density should also depend on the color and texture of the pixels between houses to, for example, treat impervious surface differently than vegetation. In CGIA we can add this dependency on the image pixels in terms of a computational geometry structure. For example, the image texture features used on the segments of an OBIA segmentation could be replaced by the same image texture computation, but with feature associated with each triangle, and with the computation over the circumscribed circle in the point's Delaunay triangulation. The Computational Geometry Algorithms Library, CGAL, Open Source Project [7] is a powerful

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000. Approved for public release; further dissemination unlimited.

starting point, with elegant implementation of geometric traits. However, CGAL does not now provide for implementing algorithms that ultimately construct statistical decision rules from pixels.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000. Approved for public release; further dissemination unlimited.

[1]	**What Is Spatial Data?** Spatial data describes the position, shape, and orientation of objects in space. In this book, as in most common applications, we are particularly concerned with describing the position and shape of objects on the earth. This is known as geospatial data. Geospatial data can describe the properties of many different sorts of *objects* on the earth. These objects might be tangible, physical things, such as an office building or a mountain, or abstract features, such as the imaginary line marking the political boundary between countries. Aitchison, Alastair; **Beginning Spatial with SQL Server 2008**; ISBN: 978-1-4302-1829-6, 2009, p. 3.
[2]	**6.1.2.4 Methods that support spatial analysis** All of the following are geometric analysis and depend on the accuracy of the coordinate representations and the limitations of linear interpolation in this specification. The accuracy of the result at a fine level will be limited by these and related issues. • Distance (anotherGeometry: Geometry):Double — Returns the shortest distance between any two Points in the two geometric objects as calculated in the spatial reference system of this geometric object. Because the geometries are closed, it is possible to find a point on each geometric object involved, such that the distance between these 2 points is the returned distance between their geometric objects. http://www.opengeospatial.org/standards/sfa

[3]	**Use case 4: Follow the geography** Alice is preparing a grant proposal to support a new recycling initiative in Nepotist County. She wants to research county-level recycling programs worldwide. Firing up her semantic search client, she initiates a SPARQL query which includes among others the concepts of "county", "spatialScaleOf", and "recycling". Referencing a geospatial ontology, the query agent infers further geospatial concepts such as county instances and the names of county equivalents such as "parish" within the state of Louisiana. Inferred queries are passed on to other query agents which resolve county locations and synonyms, as well as concepts related to "recycling" such as "waste disposal", "sanitation", and "reuse". Filter agents reason on ***spatialScaleOf*** to eliminate discovered knowledge which is too limited in scale. Semantic similarity analysis finally returns to Alice information about a recycling program only two counties over which is a good model for her proposal but has been sparsely documented as "regional resource recovery". The query agent also processes her personal context with the query and returns unexpected references to two foundations with new programs to fund combined recycling and clean government initiatives. http://www.w3.org/2005/Incubator/geo/charter#cases

[4]	Object-Based Image Analysis (OBIA) is a tentative name for a sub-discipline of GIScience devoted to partitioning remote sensing (RS) imagery into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal scale. At its most fundamental level, OBIA requires image segmentation, attribution, classification and the ability to query and link individual objects (a.k.a. segments) in space and time. In order to achieve this, OBIA incorporates knowledge from a vast array of disciplines involved in the generation and use of geographic information (GI). It is this unique focus on RS and GI that distinguishes OBIA from related disciplines such as Computer Vision and Biomedical Imaging, where outstanding research exists that may significantly contribute to OBIA. http://wiki.ucalgary.ca/page/OBIA
[5]	Definiens Developer is a powerful development environment for object-based image analysis. It is used in earth sciences to develop rule sets (or applications for Definiens Architect) for the automatic analysis of remote sensing data. Definiens Developer can be applied for all common remote sensing tasks such as vegetation mapping, feature extraction, change detection and object recognition. By using an object-based analysis approach it facilitates analysis of all common data sources like medium to high resolution satellite

	data, high to very high resolution aerial photography, lidar, radar and even hyperspectral data. http://www.definiens.com/definiens-developer-for-earth-sciences_180_7_9.html
[6]	Often the physical features of objects do not represent their semantic meaning. Therefore, the groups hierarchy allows you to group classes semantically. So, when classifying with class-related features, you can refer to groups of classes that belong to one semantic entity by referring to their parent class in the groups hierarchy. Definiens Developer - User Guide, p. 259.
[7]	**31.3 Software Design** The triangulations classes of CGAL provide high-level geometric functionalities such as location of a point in the triangulation, insertion or removal of a point. They are built as a layer on top of a data structure called the triangulation data structure. The triangulation data structure can be thought of as a container for the faces and vertices of the triangulation. This data structure also takes care of all the combinatorial aspects of the triangulation. This separation between the geometric aspect and the combinatorial part is reflected in the software design by the fact that the triangulation classes have two template parameters :

	the first parameter stands for a **geometric traits** class providing the geometric primitives (points, segments and triangles) of the triangulation and the elementary operations (predicate or constructions) on those objects. the second parameter stands for a **triangulation data structure** class. The concept of triangulation data structure is described in Section of Chapter . The triangulation data structure defines the types used to represent the faces and vertices of the triangulation, as well as additional types (handles, iterators and circulators) to access and visit the faces and vertices. http://www.cgal.org/Manual/3.4/doc_html/cgal_manual/Triangulation_2/Chapter_main.html