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The OpenGIS™ Abstract Specification
Topic 3: Locational Geometry Structures

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1. Introduction

1.1. The Abstract Specification

The purpose of the Abstract Specification is to create and document a conceptual model sufficient enough to allow for the creation of Implementation Specifications. The Abstract Specification consists of two models derived from the Syntropy object analysis and design methodology [1].

The first and simpler model is called the Essential Model and its purpose is to establish the conceptual linkage of the software or system design to the real world. The Essential Model is a description of how the world works (or should work).

The second model, the meat of the Abstract Specification, is the Abstract Model that defines the eventual software system in an implementation neutral manner. The Abstract Model is a description of how software should work. The Abstract Model represents a compromise between the paradigms of the intended target implementation environments.

The Abstract Specification is organized into separate topic volumes in order to manage the complexity of the subject matter and to assist parallel development of work items by different Working Groups of the OGC Technical Committee. The topics are, in reality, dependent upon one another— each one begging to be written first. *Each topic must be read in the context of the entire Abstract Specification*.

The topic volumes are not all written at the same level of detail. Some are mature, and are the basis for Requests For Proposal (RFP). Others are immature, and require additional specification before RFPs can be issued. The level of maturity of a topic reflects the level of understanding and discussion occurring within the Technical Committee. Refer to the OGC Technical Committee Policies and Procedures [2] and Technology Development Process [3] documents for more information on the OGC OpenGIS™ standards development process.

Refer to Topic Volume 0: Abstract Specification Overview [4] for an introduction to all of the topic volumes comprising the Abstract Specification and for editorial guidance, rules and etiquette for authors (and readers) of OGC specifications.

1.2. Introduction to Locational Geometry Structures

This Topic Volume 3, Locational Geometry, provides essential and abstract models for technology that is used widely across the GIS landscape. Its first heavy use is in support of Simple Feature geometry specification and their Spatial Reference Systems. Additional use is expected to occur in support of Coverage specifications (see Topic 6, The Coverage Type).

At the Cambridge, UK, OGC meetings, August 11-14, 1997, Simple Feature Implementation Specifications were accepted as OGC baseline, in accordance with the OGC RFP consensus process. These specifications are available at http://www.opengis.org/members/spec_rev.htm

The Implementation Specifications add implementation detail to the Abstract Model presented in this Topic Volume.

A Request for Proposals for Simple Coverages is expected to be released in early 1998. Responses to that request are expected to include significant Locational Geometry functionality. This Topic Volume will be updated upon acceptance of implementation specifications to keep it a consistent technical foundation for Coverage technology.

1.3. Many Spatial Reference Systems are Needed

1.3.1. Spatial Reference Systems provided by Topic 2

Topic 2 provides interfaces that support Geodetic and Cartographic Spatial Reference Systems.

Most abstract mathematical spaces are also supported by the interfaces in Topic 2. The Topic of this volume is intended to extend Topic 2 to include other locational systems

1.3.2. Spatial Reference Systems also needing Interfaces

There are additional coordinate systems that need to be related to the Spatial Reference Systems described so far. These include the following:

- Raster-scan geometries (where images of features have (row, column) raster position,
- Digital image geometries (where images of features also have (row, column) raster position, but now there is usually a projectivity involved besides scale, rotation, and skew
- Linear Reference and other Indirect Reference Systems.

1.4. References for Section 1

[1] Cook, Steve, and John Daniels, Designing Objects Systems: Object-Oriented Modeling with Syntropy, Prentice Hall, New York, 1994, xx + 389 pp.

[2] Open GIS Consortium, 1997. OGC Technical Committee Policies and Procedures, Wayland, Massachusetts. Available via the WWW as <http://www.opengis.org/techno/development.htm>.

[3] Open GIS Consortium, 1997. The OGC Technical Committee Technology Development Process, Wayland, Massachusetts. Available via the WWW as <http://www.opengis.org/techno/development.htm>.

[4] Open GIS Consortium, 1999. Topic 0, Abstract Specification Overview, Wayland, Massachusetts. Available via the WWW as <http://www.opengis.org/techno/specs.htm>.

2. The Essential Model for Locational Geometry Structures

2.1. General Notion of Locational Geometry

The scenario of this discussion assumes that the same Project World has been (or is to be) implemented (that is, abstracted into a feature collection) twice, using two different locational systems. A locational system is a mathematical construct providing coordinates for each corner of interest. The coordinates are usually scalars, but could be values from another domain. Here are some examples:

Locational Coordinates	Meaning of Coordinates
(x, y, z)	where x, y, and (optionally) z are real numbers (abstract geometry coordinates)
(long, lat, elev)	where long, lat, and (optionally) elev are geographic coordinates (world coordinates)
(n, x)	where n is a segment ID and x is the linear offset along the segment from the origin of the segment (linear reference coordinates)
(r, c)	where r and c are (perhaps integer or real) row and column coordinates (image or raster coordinates)
(E, N)	where E and N (Easting and Northing) are real numbers (map coordinates)

2.1.1. Features in two implementations

In this section, we assume that there is one Project World with a specific finite number of real world phenomena of interest. We will assume that the Project World has been implemented twice, yielding Feature Collection A and Feature Collection B, where A and B use different locational systems, but otherwise consist of the same features in the same feature schema. If U is a feature in A, and V is the corresponding feature in B, we say $U \equiv V$. Let X denote the locational system used by Feature Collection A, and Y denote the locational system used by Feature Collection B.

2.1.2. Definition of a Feature Preserving Function

A one-to-one function, f, from X to Y generates another function, f*, from A to B. The function, f, maps coordinates to coordinates. On the other hand, f* maps from features to features. To be specific, we say f* maps feature U in Feature Collection A to feature V in Feature Collection B if the corners of U map under f to the corners of V in the canonical manner:

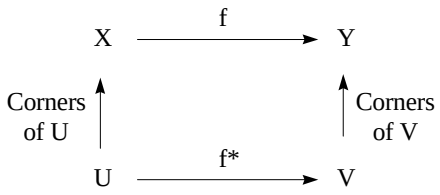

Figure 2-1. The Canonical Mapping

We say a function, f, whose domain is X and whose range is Y, preserves the features of the Project World if it supports such a canonical map for each of the Project World features.

2.1.3. A Discussion of Tolerances

The previous definition leaves no room for small inaccuracies, such as round-off error. In fact, any two implementations of the same Project World using differing Locational Reference Systems must embody small errors of observation, round-off, and errors from other sources. We therefore allow a tolerance in deciding whether a function, f, preserves the features of the Project World, or not. If the corners of U map "close enough" under f to the corners of V, we accept f as a feature preserving function.

2.1.4. Locational Geometry

Locational Geometry refers to structures that represent mappings from one locational system to another. The domain and range of such mappings can be any of the following:

1. feature geometry (abstract geometry coordinates)

2. world coordinate systems

3. map coordinate systems

4. image coordinates

5. linear reference systems

6. raster coordinates

In Topic 2, Spatial Reference Systems, we treated mappings whose domain and range are numbers 1, 4, and 5 on this list. Topic 3 is intended to extend Topic 2 to include other locational systems.

Figure 2-2 illustrates the wide variety of settings for locational geometry.

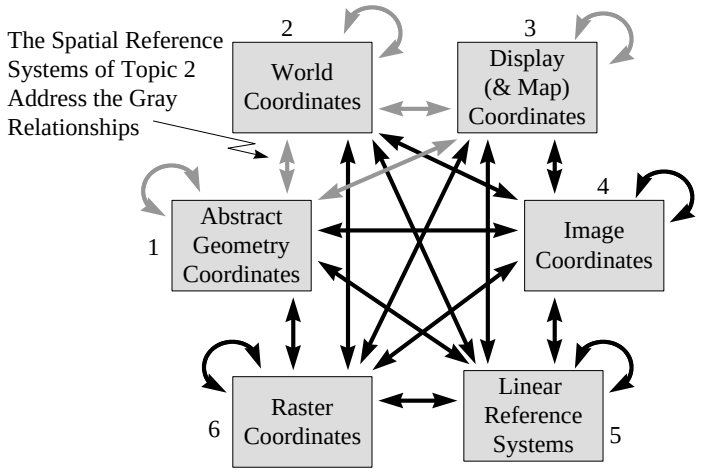

Figure 2-2. Example Domains and Ranges for Locational Geometry Functions

2.2. Interfaces on Locational Geometry

There are two fundamental interfaces on Locational Geometry:

1. Given two locational systems, construct a Locational Geometry Structure that maps the first to the second.

2. Given a Locational Geometry Structure that represents a mapping, f, from X to Y, evaluate f at a specific corner in X.

Additional interfaces that expose more details of the Locational Geometry Structure might be required for high-performance of some repetitive tasks.

2.3. Applications

2.3.1. Registration of Scanned Maps, Scanned Graphics, and Digitized Graphics

Locational Geometry Structures can serve to bring two unrelated coverages into a common geometry, and thereby creating a Family of Coverages.

Locational Geometry Structures can serve to model and eliminate non-linearities and other error sources in scanners, digitizing tablets, and other digital input devices.

Locational Geometry Structures can serve to build a geometric bridge between maps of differing scales, projections, and datums.

2.3.2. Registration of Images

Locational Geometry Structures serve to map between images and their rectified and orthorectified counterparts.

Locational Geometry Structures can serve to represent Rigorous Math Models and their Real-Time Execution counterparts in photogrammetry.

Locational Geometry Structures can serve to model and bring into alignment differing sensor systems such as radar, electro-optical, photographic, and infrared.

2.3.3. Use of Linear Reference Systems and Spatial Reference Systems

Locational Geometry Structures can serve to map between Linear Reference Systems and Spatial Reference Systems

2.4. References for Section 2

[1] OpenGIS Abstract Specification, OpenGIS Project Documents 99-100 through 99-116, available through www as <http://www.opengis.org/techno/specs.htm>.

3. Abstract Model for Locational Geometry Structures

Development of the Abstract Model describing software interfaces and their behavior for Locational Geometry is TBD.

3.1. References for Section 3

[1] OpenGIS Abstract Specification, OpenGIS Project Documents 99-100 through 99-116, available through www as <http://www.opengis.org/techno/specs.htm>.

4. Future Work

Development of the Abstract Model for Locational Geometry remains to be completed.

The work on Locational Geometry may in the future be subsumed by more fundamental work in the technology of stored functions.

Additional work is needed on the Well Known Structures that will carry the Stored Function types and parameters.

5. Appendix A. Well Known Structures

We know that WKS for stored function types and parameter lists are needed.

Other WKS are TBD.