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The OpenGIS™ Specification Model

Topic 15: Image Exploitation Services

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Revision History

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15 January 1999	New topic volume from project document 98-025r4.
31 March 1999	Update Section 1 for new document template; move introduction of Section 2 and Section 2.1 in 99-115 to Section 1.2 of this version.
22 June 1999	Update sections 2.1.1.1, 2.1.1.2 and 2.1.3 with change proposal 99-025 (w/ friendly changes), approved at April 1999 TC meeting.
14 December, 1999	Update Section 2.1.1.1 with change proposal 99-059, approved at the October 1999 TC meeting.

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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 Image Exploitation Services

This topic volume is the portion of the OpenGIS™ Abstract Specification that describes the categories and taxonomy of image exploitation services needed to support the use of images and certain related coverage types. The Image Exploitation Services SIG of the Core Task Force is using this categorization to organize their work, especially development of more detailed abstract specification material for each service category.

Image exploitation services are required to support most aspects of image exploitation, including precision measurement of ground positions and of object dimensions. For example, a variety of services are needed for extracting features from images, or digital elevations from stereoscopic images. Image exploitation services are widely implemented and used in photogrammetric systems, currently using custom interfaces. Although the focus of this document is on services for using images, many of these services are expected to also be applicable to using other types of grid coverages and some non-grid coverages.

1.3. 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. Background for Image Exploitation Services

2.1. Use Cases

This Section presents a set of use cases that have been defined to support the definition the needed image exploitation services. That is, most listed steps in each use case will use one or more image exploitation services. These use cases start to show how image exploitation services are used in the "real world." This Section also starts to define the image exploitation services that are needed by each use case. These use cases are grouped into two types: information consumer and information producer.

2.1.1. The Information Consumer Perspective

The following "use cases" describe several possible situations in which information consumers could perform activities that require uses of image exploitation services.

2.1.1.1. The Farmer

A farmer has the goal of making management decisions on the application of insecticide, fertilizer, and irrigation to his fields. To do this:

1) The farmer obtains a map of his fields, through an interface to a local or remote map library or to a map creation service. (Note that this interface determines the spatial datum and projection and scale, or units, of the map). The farmer overlays this map with:

a) One or more previous images of his fields, orthorectified to overlay the map (obtained from a local or remote crop image library),

b) One or more previous years crop yield results (note that the yield information might be grid coverages, linear features, or polygon features),

c) Soil sample results, recent and previous (note that the soil samples are point features),

d) Selected scouting reports (note that the scouting reports may be point features).

2) Using this data, the farmer assesses the need for fertilizer as a function of location in his fields. (Note that the algorithm which estimates the fertilizer need requirements may be provided by the local farmer's cooperative. That algorithm uses the map, current crop image, previous years yields, and soil samples as input.) The fertilizer need function produces a coverage that aligns with the farmer's fields, where each polygon represents certain fertilizer application requirements.

3) The farmer can use historical data to find areas of crop damage due to insects, and determine appropriate corrective action. The need for insecticide is estimated using multispectral images from each of the past five years that have been processed to highlight insect infestation. (Note that the multispectral images are obtained via an interface to USDA's database, with rectification parameters that ensure that it will fit the map automatically. The "insecticide need" is a partition of the farmer's fields into polygons, each of which specifies a certain mixture and concentration of chemicals. The algorithm that computes these polygons and concentrations from the multispectral imagery is provided by the local extension service.)

4) To help minimize the environmental impact of applying fertilizer and pesticides, the decision support tools would use additional data. These tools overlay the "insecticide need" polygons and values, and the "fertilizer need" polygons, with wetlands data from the county or state (note that the wetlands data is a vector file), together with sensitivity factors from the Fish and Wildlife office (this is a raster file). Then, using an algorithm from the EPA, the farmer modifies his insect and fertilizer plans to protect a creek natural habitat of an endangered species.

5) The farmer generates an irrigation schedule for today and tomorrow. The irrigation need is determined by an algorithm using weather data (obtained from a weather prediction service), soil samples, and the current soil moisture profile (obtained through an interface to NASA's real-time data).

6) The farmer can review all the data to detect small areas (or points) where needed or useful data is missing or ambiguous. The farmer can then select a few specific areas where future scouting reports would probably be beneficial.

Notice the various actors: the farmer, the state university extension service (with insect data), the EPA, fish and wildlife, the farmer's cooperative (with algorithms), the image library (could be a commercial or a government source), USGS, etc.

Note that the selective application of fertilizer, insecticide, and irrigation probably would be done by computer controlled farm equipment using GPS. Similarly, crop yield information would be automatically collected by harvesting equipment using GPS.

Notes: The above discussion assumes irrigation is being used. In some farming areas, irrigation is always used. However, irrigation is never used in other farming areas. Other aspects of the above use case are probably applicable to some farming areas but not to other areas.

The above discussion assumes that algorithms and data are supplied by outside agencies such as the farmer's cooperative, the state university extension service, etc. However, outside sources (particularly those supplying material and services) may not be the best source of algorithms. The farmer has a personal and vital interest in the results, and wants to avoid bias if possible. The farmer must at least retain understanding and customizing capability. He also needs to retain data ownership rights over his operation. That said, there can be value in getting the viewpoint of someone who sees a lot of other surrounding operations for comparison.

Table 2-1 summarizes the steps in this use case and lists some of the image exploitation services needed by each step.

Use Case Step	Image Exploitation Services Used
1) Obtains map of his fields	
a) overlays it with images of his fields	Display image with overlaid graphics
b) overlays that with crop yield results	Display image with overlaid graphics
c) overlays that with soil sample results	Display image with overlaid graphics
d) overlays that with scouting reports	Display image with overlaid graphics
2) Assesses need for fertilizer as function of location in fields (displaying fertilizer need)	Classify pixels and segment image, Display image with overlaid graphics
3) Overlays all previous data with multispectral images from each of past 5 years	Display image with overlaid graphics
a) processed to highlight insect infestation	Classify pixels and segment image
b) assesses need for insecticide (displaying insecticide need)	Classify pixels and segment image, Display image with overlaid graphics
4) Overlays (above) with wetlands data	Display image with overlaid graphics
a) together with sensitivity factors	Display image with overlaid graphics
b) modifies insect and fertilizer plans to protect creek	Classify pixels and segment image, Display image with overlaid graphics
5) Generates irrigation schedules	
a) overlays all above with soil moisture profile	Display image with overlaid graphics
b) determines irrigation need	Classify pixels and segment image, Display image with overlaid graphics
6) Reviews all data to detect areas where useful data is missing or ambiguous	Display image with overlaid graphics
a) selects areas for future scouting reports	Classify pixels and segment image, Display image with overlaid graphics

Table 2-1. Image Exploitation Services Needed by "The Farmer"

2.1.1.2. The Prospective Home Buyer

The buyer, in the real estate broker's office or from home, selects a neighborhood (from an Internet service provided to support home-buying in a region), and is provided an aerial view of it. Service functions allow the buyer to zoom and roam through the region covered by the broker or service provider. Houses for sale appear in a red tint. Service interfaces allow the buyer to state a price range and mandatory features. Houses for sale in the desired price range and with the mandatory features flash red and green.

A few candidate green-and-red homes are selected through interfaces provided to the prospective buyer.

Functions using elevation data produce a three-dimensional perspective that allows the buyer to assess the view from each back porch.

A function that allows a virtual walk-through of the rooms of the house may be available.

Using orthorectified county imagery from 5, 10, 15, and 20 years ago, the buyer assesses the age of the roof, the health of the trees, and the trends in the neighborhood.

Using city, county and state data, the imagery is superimposed with:

1. Underground pipe and wire information (linear features);

2. The assigned school districts and schools (point and area features)

3. The nearest hospital and fire station

4. The lot lines

5. All easements and right-of-ways.

Using chamber of commerce data, the nearest shops and supermarket and auto repair shops are located and superimposed.

Using Automobile Association data, a family of alternate routes to work are determined, with the conditions that make each optimal. Each route is displayed, registered to the image backdrop.

Using thermal infrared imagery from the department of energy, the prospective buyer assesses the heat loss in winter, and the need for new insulation. The algorithm is provided by EPA and DoE, jointly.

Using measuring tools, the sizes of the lot and house are separately measured. The size of the parking area is assessed and compared to the number of cars owned by the buyer.

Using census tract data and interfaces provided to the buyer, the demographics of the neighborhoods are visualized.

Table 2-2 summarizes the steps in this use case and lists some of the image exploitation services needed by each step.

Use Case Step	Image Exploitation Services Used
1) Selects neighborhood and is provided aerial view of (neighborhood)	
a) Selects neighborhood	
b) provided aerial view of (neighborhood)	Display image
c) Houses for sale appear in red tint (or) flash red and green	Display image with overlaid graphics
2) A few candidate homes are selected by prospective buyer	Display image with overlaid graphics
3) (Display) artificial perspective (of) view from each back porch	Generate perspective scene, Display image (with overlaid graphics?)
4) Virtual walk-through of rooms of house	Generate perspective scene, Display image (with overlaid graphics?)
5) Assess age of roof, health of trees, and trends in neighborhood, using county imagery from 5, 10, 15, and 20 years ago	Classify pixels and segment image, Display image with overlaid graphics

6) Imagery is superimposed with: a) underground pipe and wire information b) school districts and schools c) nearest hospital and fire station d) lot lines e) easements and rights of way	Display image with overlaid graphics
7) Nearest shops and supermarket and auto repair shops are located and superimposed	Display image with overlaid graphics
a) Using chamber of commerce data or images	Classify pixels and segment image?
8) Family of alternate routes to work are charted, with conditions that make each optimal	
a) Using Automobile Association data	
b) Each is registered to image backdrop	Display image with overlaid graphics
9) Assesses heat loss in winter, and need for new insulation, using thermal infrared imagery. The algorithm is provided by EPA and DoE jointly.	Classify pixels and segment image
a) (display color coded heat loss rating results)	Display image with overlaid graphics
10) Size of lot and house are independently measured	Compute area of polygon visible in image
11) Size of parking area is assessed and compared to number of cars owned by buyer	Compute area of polygon visible in image, Compute length of object visible in image
12) Demographics in neighborhoods are visualized, using census tract data	Display image with overlaid graphics

Table 2-2. Image Exploitation Services Needed by "The Home Buyer"

The image exploitation services listed above assume:

1. All displays are in a (scaled and windowed) ground coordinate system (not in an unrectified image coordinate system).

2. Selection of a neighborhood is done using either a text menu or a graphic map display (not using an image display).

3. Virtual walk-through of a house is done using images of the house interior.

2.1.1.3. The Soldier

The soldier is on a peacekeeping mission. He uses information from surveillance cameras in planes, drones, and satellites. He receives video day and night in a continuous stream from lightweight airborne platforms, and he receives still images periodically. [Interfaces allow the soldier to selectively archive interesting imagery, and to retrieve it using categories of interest.]

He is able to pass the imagery through feature detection algorithms (looking for airplanes, rockets, artillery, etc.) that may be local or remote. The soldier (or the detection algorithm) can automatically bring up yesterday's image whenever something is suspicious in order to reduce the number of false "hits". If an interesting spot wasn't covered yesterday, older imagery is can be provided and used.

The image detection algorithms need to know where the roads are in the images, so an interface is provided that projects roads into the image geometry. Of course this assumes a prior interface that registers the road data to the images.

Image coordinates (pixel row and column) are automatically converted to the position data needed by his ordnance (that is, point and aim information). All the types of ordnance understand the target position objects; conversion is not necessary. [That is, a common interface exposes target positions.]

The soldier is in contact with his command authority; they share a common view of the battle space. [That is, there is a single interface (or family of interfaces) exposing a view of the battle space.]

The soldier finds something of interest on an image. He points at it and with a simple interface generates a report instantly that is understood by other analysts, who check his finding using other sources.

The other analysts are coalition members who speak a different language, and are supported with different technology, and who use different datums and projections. Yet interfaces bridge these gaps.

The soldier in his spare time makes contingency mission plans: selects potential targets, finds optimum access and egress paths, prepares flight folders that pilots and other weapon control officers can use to train, navigate, execute, escape, etc. [Note that interfaces exist to create and modify mission plans, and that mission plans include coordinated maps, images, vector and coverage features, …]

Table 2-3 summarizes the steps in this use case and lists some of the image exploitation services needed by each step.

Use Case Step	Image Exploitation Services Used
1) Uses information from surveillance cameras in planes, drones, and satellites	
a) receives video in a continuous stream, and receives still images periodically	Display still image, Display video images
b) selectively archive interesting imagery	Capture selected frame of video image
c) retrieve (archived images) using categories of interest	
2) Pass imagery through feature detection algorithms	Automated feature detection
a) bring up yesterday's (or older) image whenever something is suspicious	Display images, Automated feature detection
b) to reduce the number of false "hits"	Automated feature detection
3) Know where roads are in images	
a) projects roads into image geometry	Display image with overlaid graphics
b) registers road data to images	Register images to ground control

4) Image coordinates ... converted to position data needed by ordnance (point and aim information)	Compute ground from image positions, Transform ground coordinates
5) Share common view of battle space with command authority	Transform ground coordinates, Compute ground from image positions, Compute image from ground positions
6) Points at something of interest on image and generates report instantly, understood by other analysts, who check his finding	Compute ground from image positions, Transform ground coordinates, Automated image report generation, Display image with overlaid graphics
7) Other analysts speak a different language, are supported with different technology, and use different datums and projections	Transform ground coordinates
8) Makes contingency mission plans:	
a) selects potential targets	Compute ground from image positions, Transform ground coordinates
b) finds optimum access and egress paths	
c) prepares flight folders, etc.	Automated image report generation

Table 2-3. Image Exploitation Services Needed by "The Soldier"

The listed services assume that all displays are in a (scaled and windowed) un-rectified image coordinate system (not in a ground coordinate system).

2.1.2. The Information Producer Perspective

Figure 2-1 is a UML diagram of the five use cases defined in this Section. Each of these five use cases is defined and described in the following subsections. These five use cases show steps of a workflow used by information producers to extract geospatial data from images. They were derived from the conceptual process for geospatial data extraction described in Section 7 (Appendix B. The Geospatial Data Extraction Process). The five use cases presented in this section represent only a few of the many possible image exploitation scenarios that can be derived from the conceptual model of Section 7. Refer also to Section 8 (Appendix C. OGC Image Levels) for a description of the OGC standard set of image levels to be used in labeling processed images.

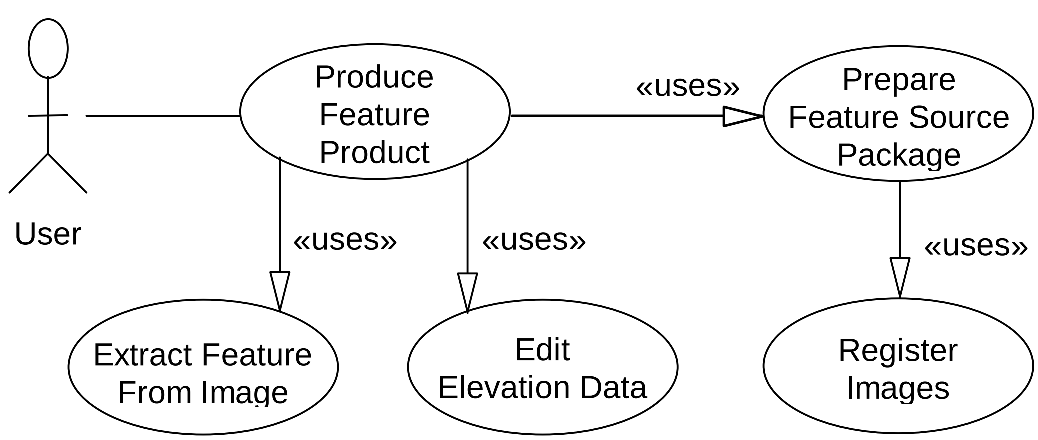

Figure 2-1. Use Cases for Extracting Geospatial Information from Images

2.1.2.1. Produce Feature Product

In the Produce Feature Product use case, the actor is a user of a photogrammetric system (sometimes called an operator, a photogrammetrist, or a cartographer). This use case is started when the user starts to produce a specific feature product. The assumptions made in this use case include:

1. A feature product is (all or mostly) a collection of features with geometry, and/or one or more coverages based on feature collections.

2. Images plus existing vector feature data are used to produce the new feature product.

3. Elevation data is needed to obtain correct horizontal positions from feature positions in images.

4. A feature product may include elevation data, in feature geometry vertices and/or separately

5. An external use case handles decisions to produce feature products, plus any needed assignment and scheduling of users and systems.

Table 2-4 summarizes the steps in this use case and lists some of the image exploitation services needed by each step. Some of the use case listed in the table are optional. Several of these steps could be lower level use cases, such as the fourth step “Edit existing feature”. This table also lists some of the metadata used and generated by each step.

Use Case Step	Image Exploitation Services Used	Metadata Used	Metadata Generated
1) Prepare feature source package, to be used to produce product	(see separate use case)	(see separate use case)	(see separate use case)
2) If needed, edit elevation data covering product area	(see separate use case)	(see separate use case)	(see separate use case)
3) Display features graphically overlaid on images (display both existing and newly extracted features)	Display images with overlaid graphics, Enhance images	SRS for features, SRS for images	-
4) If needed, edit existing feature for inclusion in new product (repeat for each existing feature to be included in product)	Classify and segment image	Quality of existing features	Quality for new product
5) Extract feature from image (repeat for each new feature to be included in product)	(see separate use case)	(see separate use case)	(see separate use case)
6) Check new product			
a) Review all features in product, separately and overlaid on images	Display images with overlaid graphics, Enhance Images, Classify and segment image	SRS for features, SRS for images	Quality for new product
b) Evaluate quality of new product		?	Quality for new product
7) Release new feature product		-	Store all metadata for new product

Table 2-4. Image Exploitation Services Used to Produce Feature Product

Some of the possible variations in this use case are:

1. Nature of feature product, either:

1.1. Updated existing product

1.2. New product

2. Elevation values attached to feature vertices, either:

2.1. No elevation values recorded

2.2. Elevation values automatically obtained from elevation data

2.3. Elevations values extracted from stereoscopic images (with horizontal positions)

3. Type of images from which features are extracted or edited, either:

3.1. Stereoscopic images

3.2. Unrectified monoscopic images

3.3. Rectified monoscopic images

3.4. Orthorectified monoscopic images

3.5. Mosaicked monoscopic images, normally orthorectified first

2.1.2.2. Extract Feature from Image

In the Extract Feature from Image use case, the actor is a user of a photogrammetric system (sometimes called an operator, a photogrammetrist, or a cartographer). This use case is started when the user decides to extract a new feature from displayed image(s). The assumption made in this use case is that a feature with geometry is to be extracted.

Table 2-5 summarizes the steps in this use case and lists some of the image exploitation services needed by each step. Some of the use case steps listed in the table are optional. Several of these steps could be lower level use cases. This table also lists some of the metadata used and generated by each step.

Use Case Step	Image Exploitation Services Used	Metadata Used	Metadata Generated
1) Delineate new feature geometry in image(s)	Classify and segment images, Delineate feature positions	-	Quality for delineation
2) Convert feature geometry to product SRS	Convert image positions to product SRS	SRS for image, SRS for new product, Quality for delineation	Quality for new feature
3) If needed, measure dimension of feature from images, in product SRS (for example, measure feature height or width)	Delineate feature positions, Measure object dimensions	See step 2, Feature attributes for new product	Quality for new feature
4) Assign type and all attributes to feature		Feature types and attributes for new product	Quality for new feature
5) Automatically check extracted feature		Feature types and attributes for new product	Quality for new feature
6) Display new feature overlaid on image(s)	Display images with overlaid graphics, Convert ground positions to image SRS	SRS for image, SRS for new product	-
7) Review extracted feature		?	Quality for new feature

Table 2-5. Image Exploitation Services Used to Extract Feature from Image

Some of the possible variations in this use case are:

1. Type of images from which features extracted or edited, either:

1.1. Stereoscopic images

1.2. Unrectified monoscopic images

1.3. Rectified monoscopic images

1.4. Orthorectified monoscopic images

1.5. Mosaicked monoscopic images, usually orthorectified first

2. Elevation values attached to feature vertices, either:

2.1. No elevation values recorded

2.2. Elevation values automatically obtained from elevation data

2.3. Elevations values extracted from stereoscopic images (with horizontal positions)

2.1.2.3. Edit Elevation Data

In the Edit Elevation Data use case, the actor is a user of a photogrammetric system (sometimes called an operator, a photogrammetrist, or a cartographer). This use case is started when the user decides to edit or extract elevation data.

Table 2-6 summarizes the steps in this use case and lists some of the image exploitation services needed by each step. Some of the use case steps listed in the table are optional. Several of these steps could be lower level use cases. This table also lists some of the metadata used and generated by each step.

Use Case Step	Image Exploitation Services Used	Metadata Used	Metadata Generated
1) Obtain stereoscopic images suitable for extracting elevations, with image support data (perhaps obtain images from an image library or archive)	Display images with overlaid graphics? Enhance images?	Found using metadata for images, Obtained with support metadata	-
2) Display elevation data graphically overlaid on stereoscopic images (display both existing and newly extracted elevations)	Display stereoscopic images with overlaid graphics, Convert ground positions to image SRS	SRS for elevation data, SRS for images	Quality of parallaxes
3) Where needed, edit existing elevation point (repeat for each existing elevation point to be edited)	see step 2	See step 2, Accuracy for existing elevation point	Modified accuracy for elevation point
4) Where needed, extract new elevation point (repeat for each new elevation point needed)	see step 2, Automatically measure point elevation, Manually measure point elevation	See step 2, Image accuracy	Accuracy of new elevation point
5) Display (new or edited) elevation point graphically overlaid on images	see step 2	See step 2	-
6) Check modified elevations			
a) Review all elevations, separately and overlaid on images		See step 2, Quality for modified elevation data?	Quality for modified elevation data?
b) Evaluate quality of elevation data		?	Quality for modified elevation data
7) Release modified elevation data		-	Store all metadata for edited elevation data

Table 2-6. Image Exploitation Services Used to Edit Elevation Data

Some of the possible variations in this use case are:

1. Nature of elevation data, either:

    1.1. Grid elevation data

    1.2. TIN elevation data

    1.3. Contour lines

    1.4. Geomorphic features (that is, ridge lines, valley lines, slope break lines, peak points, saddle points, etc.)

    1.5. Combination of above

2. Nature of elevation extraction, either:

    2.1. Edit existing elevation data (e.g., improve accuracy, density, etc.)

    2.2. Extract new elevation data (in part or all of product area)

    2.3. Combination of above

2.1.2.4. Prepare Feature Source Package

In the Prepare Feature Source Package use case, the actor is a user of a suitable source package preparation system. This use case is started when the user begins to prepare to produce a specific feature product. The assumptions made in this use case include:

1. Images plus existing vector feature data are used to produce the feature product,

2. Elevation data is needed to obtain correct horizontal positions from feature positions in images,

3. An external use case handles decisions to produce feature products, plus any needed assignment and scheduling of users and systems.

Table 2-7 summarizes the steps in this use case and lists some of the image exploitation services needed by each step. Some of the use case listed in the table are optional. Several of these steps could be lower level use cases. This table also lists some of the metadata used and generated by each step.

Use Case Step	Image Exploitation Services Used	Metadata Used	Metadata Generated
1) Define feature product to be extracted, including:			
a) If new product is in a series or of a standard type, obtain definitions of product series or type		Various metadata for product series or type	-
b) Define product Spatial Reference System (SRS)		SRS for product series or type	SRS for new product
c) Define product area to be covered (in product SRS)		Covered area for product series or type	Covered area for new product
d) Define feature types and attributes for use in product		Feature types and attributes for product series or type	Feature types and attributes for new product
2) Obtain existing feature data suitable for use and connection to by product (obtaining feature data from		Found using metadata for feature data, Obtained with feature metadata	Source for new product

a product library or archive)			
3) Obtain images suitable for producing product, with image support data (perhaps obtain images from an image library or archive)	Display images with overlaid graphics?	Found using metadata for images, Obtained with image metadata	Source for new product
4) Obtain existing elevation data covering product area (obtaining elevation data from a library or archive)	Display images with overlaid graphics?	Found using metadata for elevation data, Obtained with elevation metadata	Source for new product
5) If needed, register images to each other and to existing feature and elevation data (see separate use case)	(see separate use case)	(see separate use case)	(see separate use case)

Table 2-7. Image Exploitation Services Used to Prepare Feature Source Package

Some of the possible variations in this use case are:

1. Nature of feature product, either:

    1.1. Updated existing product

    1.2. New product in a standard series of products

    1.3. New product of a predefined type of products

    1.4. Completely custom product

2. Type of images from which features to be extracted or edited, either:

    2.1. Stereoscopic images

    2.2. Unrectified monoscopic images

    2.3. Rectified monoscopic images

    2.4. Orthorectified monoscopic images

    2.5. Mosaicked monoscopic images, usually orthorectified first

2.1.2.5. Register Images

In the Register Images use case, the actor is a user of a suitable photogrammetric system. This use case is started when the user decides that one or more images need to be registered to each other and/or to existing digital feature and elevation data. The assumptions made in this use case include:

1. One or more images plus existing data are to be used to produce feature and/or elevation products, and the existing mathematical models of (some of) these image geometries are not as accurate as needed.

2. For registration, the existing image geometry models will be adjusted by a mathematical process that uses the positions of multiple points as measured in the images being adjusted.

3. The points used in adjustment include “control” points and/or “tie” Points. Control points are points whose ground coordinates are known (with some accuracy), in three, two, or just one dimension. Tie points are points whose ground coordinates are not known (with useful accuracy), but which can be measured in two or more overlapping images.

4. Control points are selected from existing feature and/or elevation data. Some of this existing data will be used in the new product, or is in existing adjacent products with which the new product should be consistent. Other existing data may also be used, that is not to be used in the product. Specifically, “ground control” point features may exist for this purpose which have higher accuracies and/or include supplementary information to help find the proper point in the image(s).

Table 2-8 summarizes the steps in this use case and lists some of the image exploitation services needed by each step. Some of the use case listed in the table are optional. Several of these steps could be lower level use cases, especially the step “Compute corrected image geometry models”. Indeed, a variety of different use cases for that step could be defined, using different methods for computing the corrected geometry models using the point data. This table also lists some of the metadata used and generated by each step.

Use Case Step	Image Exploitation Services Used	Metadata Used	Metadata Generated
1) Obtain the existing parameter values of the image geometry models for all images to be registered. These parameter values include information for each individual image, such as camera position data collected at the time of image exposure using the Global Positioning System (GPS) or an Inertial Navigation System (INS). These parameter values also include data common to multiple images, such as camera calibration information.		Current image geometry	-
2) Obtain additional existing feature data suitable for use as control points in the registration process (obtaining feature data from a library or archive)	Display images with overlaid graphics?	Found using metadata for feature data, Obtained with feature metadata, SRS for images	Source for image registration
3) Obtain additional existing elevation data suitable for use in the registration process (obtaining elevation data from a library or archive)	Display images with overlaid graphics?	Found using metadata for elevation data, Obtained with elevation metadata, SRS for images	Source for image registration
4) Select suitable control points in the existing feature and/or elevation data	Display images with overlaid graphics	Feature position accuracy, SRS for features, SRS for images	Control point accuracy
5) Select suitable tie points	Display images with overlaid graphics, Measure point positions, Automatically select tie points	Current image geometry	Image position accuracy
6) Measure the position of each selected control point in one or more of the images in which that point is visible	Display images with overlaid graphics, Automatically measure corresponding image positions, Manually measure corresponding image positions	Current image geometry, SRS for features, SRS for images	Image position accuracy
7) Measure the position of each selected tie point in each other image in which that point is visible	see step 6	Current image geometry	Image position accuracy
8) Check all point position data for consistency, to detect any	Display images with overlaid graphics	See step 6	

major errors (or blunders)			
9) Correct or eliminate the point position data detected as erroneous	Display images with overlaid graphics	See step 6	
10) Compute corrected values for selected parameters of the image geometry models for all images, so as to obtain the best practical fit to the known ground and image positions of all selected control and tie points	Register images/geodata, Convert ground position to image SRS, Convert image position to ground SRS	See step 6	Modified image geometry, Image accuracy data
11) Check corrected image geometry models, to detect any major errors (or blunders)	Display images with overlaid graphics	Modified image geometry	Image accuracy data
12) Record corrected image geometry model data, in a form suitable for setting up images for data extraction		Modified image geometry, Image accuracy data	Store modified image metadata

Table 2-8. Image Exploitation Services Used to Register Images

> Technical Note: Position accuracy data is often required for ground and image coordinates that are generated or used. Methods need to be developed for determining the accuracy and other quality metadata listed above under Metadata Generated. The draft of ISO 15046-14 specifies some quality determination methods. Some other quality determination methods also exist, but they are not complete and are of questionable reliability.)

Some of the possible variations in this use case are:

1. Lines can be used for image registration in addition to points, or instead of points, perhaps called "control lines" and "tie lines". The corresponding positions of lines can be matched in one less dimension than for points: one dimension instead of two dimensions for image positions.

2.1.3. Description of Some Services

This section describes in more detail some of the image exploitation services listed for steps the above use cases.

2.1.3.1. Display Image With Overlaid Graphics

As listed above, many use case steps display an image, usually with overlaid graphics. The overlaid graphics are used to display features or elevations plus measurement cursors and perhaps other information. Such image display uses a number of image exploitation services, including:

1. Retrieve selected image window from larger image, centered on a specified image position (roaming) and with a specified window size (zooming).

2. Resample pixels of retrieved image window to change pixel spacing (zooming).

3. Enhance images, to make desired features more easily visible

4. Rectify or orthorectify original image, either whole image or retrieved window of image.

5. Mosaic multiple rectified or orthorectified images (mosaicking is not always needed).

6. Convert data positions stored in another coordinate system into the ground coordinate system of the display window.

7. Convert data positions stored in all other coordinate systems into the image coordinate system of the display window.

8. Allow user to pick a graphically displayed item, and then present a full description of the selected item.

Items 4 through 6 listed above are appropriate when the display is in a ground-position-based coordinate system, as assumed for “The Farmer” and “The Prospective Home Buyer” use cases. When the display is in an image-position-based coordinated system, as assumed for “The Soldier” use case, items 4 through 6 above are replaced by item 7.

Many items listed above could be done in real-time for just the portion of the images being displayed, as implied in the above list. Alternately, these operations could be done in a pre-processing step for the entire images. In that case, these operations could be done as a step 6 at the end of the Prepare Feature Source Package use case

2.1.3.2. Generate Perspective Scene

Generation of a perspective scene (or image perspective transformation) is the generation of a synthetic image by processing one or more actual images. Each synthetic image is generated to simulate a different image geometry, such as an image taken from a different point in space and/or looking in a different direction. In addition to using one or more actual images, perspective scene generation uses data defining the (approximate) shape of the visible surface that was imaged. This shape data is usually derived from grid elevation data, and can include vector feature 3-D shape data.

2.1.3.3. Classify Pixels and Segment Image

As listed, many use case steps classify image pixels and segment the resulting image (or raster data set). Such image manipulation can use a number of image exploitation services, including:

1. Register multiple images, coverages, and feature collections to one another.

2. Reproject and resample vector feature coverages and raster image coverages to one another, or to a third common coverage scheme (e.g. grid).

3. Change pixel values, to make the properties of interest more easily visible (including reduction of effective "noise"). These imagery enhancement operations can use (input) data from only one pixel at a time, or from a small neighborhood of adjacent pixels.

4. Apply previously defined classification or other analysis algorithms to multispectral pixel data. These classification or analysis algorithms can:

   - Produce results that are discrete (assigning each pixel to one of several possible categories) or continuous (assigning a numeric value to each pixel, as derived from a continuous function).
   - Use data from only one pixel at a time, or from a small neighborhood of adjacent pixels.
   - Use multiple bands from the same image or from different images that have been registered to each other (see item 1). One or more bands can also be non-image coverages, that are registered to all other data.

5. Segment classified or analyzed image into discrete regions with similar properties, by finding groups of adjoining pixels with the same or similar values. The segmentation results can be produced in either raster or vector form. Such segmentation usually ignores single pixels or very small regions that may differ from all surrounding pixels.

2.1.3.4. Automated Feature Detection

Automated feature detection can also use a number of image exploitation services, including all those listed above for Classify Pixels and Segment Image. The results of such Classify Pixels and Segment Image operations are then automatically and/or manually analyzed to detect the feature types of interest and their attributes. Alternately or in addition, the image being analyzed can be compared with sample images showing the feature types of interest.

Automated feature detection is largely outside the defined scope of the Image Exploitation Services SIG, so these services are not further detailed here.

2.2. Image Exploitation Services Categorization and Taxonomy

The following outline summarizes the current categorization and taxonomy of needed image exploitation services.

1. Ground Coordinate Transformation Services:

    1.1. Ground coordinate conversion (exact) services:

        1.1.1. Geodetic coordinate conversion services

        1.1.2. Map projection conversion services

    1.2. Ground coordinate transformation (approximate) services:

        1.2.1. Datum transformation services

        1.2.2. Affine 2-D transformation service

        1.2.3. General 2-D Polynomial transformation service

        1.2.4. Polynomial 3-D transformation service

        1.2.5. Vertical ground position transformation services

        1.2.6. Other 3-D coordinate transformation services

        1.2.7. Other 2-D horizontal ground position transformation services

    1.3. Concatenated ground coordinate transformation services (including two or more of the above transformations and/or conversions):

        1.3.1. 3-D to 3-D concatenated transformation

        1.3.2. 2-D to 2-D concatenated transformation

        1.3.3. 1-D to 1-D concatenated transformation

2. Image Coordinate Transformation Services:

    2.1. Image-ground position transformation services:

        2.1.1. Ground to image position transformation service (3-D to 2-D)

        2.1.2. Stereoscopic images to ground position transformation service (multiple 2-D to one 3-D)

        2.1.3. Monoscopic image plus elevation to ground position transformation service (2-D plus elevation to 3-D)

        2.1.4. Monoscopic image plus other data to ground position transformation service (2-D plus other data to 3-D)

    2.2. Image position transformation services: (2-D to 2-D)

        2.2.1. Polynomial transformation service

        2.2.2. Image to rectified image position transformation service

        2.2.3. Rectified image to image position transformation service

    2.3. Concatenated image coordinate transformation services (including two or more of the above image transformations plus ground coordinate transformations and conversions):

        2.3.1. 3-D to 2-D concatenated transformation

        2.3.2. 2-D to 3-D concatenated transformation

        2.3.3. 2-D to 2-D concatenated transformation

    2.4. Imaging time determination service

3. Image Modification Services:

3.1. Change pixel values services:
(Note: Includes previously defined simple pixel manipulation services)

3.1.1. Tone modification services

3.1.2. Spatial filtering (or convolution) services

3.1.3. Pixel (multi-band or multi-image) classification services

3.1.4. Image segmentation services

3.1.5. Band and image combination services

3.1.6. Other image enhancement services

3.1.7. Simulate non-idealities services

3.1.8. Histogram generation service

3.1.9. Fourier analysis service

3.1.10. Other frequency domain services

3.1.11. Graphical overlay application service

3.1.12. Grid overlay generation service

3.2. Change pixel positions services:

3.2.1. Pixel resampling service (services used by following subtypes)

3.2.2. Polynomial transformation warping service

3.2.3. Computer graphics warping services (including splines, piece-wise transformations)

3.2.4. Image rectification service

3.2.5. Orthorectification service

3.2.6. Image mosaicking service

3.2.7. Perspective scene generation service

3.3. Change image data format services:
(Note: Includes or uses image coverage access services)

3.3.1. Image section retrieval services

3.3.2. Image section replacement services

3.3.3. Tiling change services

3.3.4. Reduced resolution generation service

3.3.5. Increased resolution estimation (or creation) services

3.3.6. Image compression and decompression services

3.4. Composite image modification services, including two or more of above image modifications

4. Dimension Measurement Services:

4.1. Line segment dimensions service:

4.1.1. Compute horizontal length and azimuth angle of a line segment, from one point to a second point

4.1.2. Compute 3-D length and direction angles of a line segment, from one point to a second point

4.2. Multi-segment line length service:

4.2.1. Compute length of multi-segment line feature or real world object, from sequence of vertices representing spatial position of that line

4.3. Area dimensions services:

4.3.1. Compute area and perimeter of area feature or real world object, from sequence of vertices representing boundary of that area

4.3.2. Compute size, orientation, and center position of a standard geometrical shape, from a sequence of points on the perimeter of that shape

4.4. Height dimension service:

4.4.1. Compute height of a vertical real-world object (such as a pole or building), from one point on the image of the top and a second point on the image of the base

4.4.2. Compute height of a vertical real-world object (such as a pole or tower), from one point on the image of the top and a second point on the image of the shadow of the first point

4.5. Volume dimension service:

4.5.1. Compute volume of a solid features using its shell, from a sequence of vertexes for each facet of the shell.

4.5.2. Compute cut and fill volumes between two different elevation surfaces, specified by a digital terrain matrix, regular triangulated network, or triangulated irregular network.

4.6. Temporal dimension service:

4.6.1. Support time-stamping of features, or of each vertex of a feature, as a single value or as a time range. (The image exposure time of the feature, or its vertexes, could be associated with each feature or its vertexes. A feature time-stamp can be stored in feature attribute (or property) fields, using separate attributes for the beginning and ending times. A vertex time-stamp can be stored as a fourth dimension.)

5. Geodata Registration Services:

5.1. Adjust one SRS (Spatial Reference System) to another SRS.

5.2. Adjust multiple SRSs to each other (but not adjust to a fixed SRS)

5.3. Adjust multiple SRSs to a fixed SRS and to each other

6. Automated Image Matching Services:

6.1. Basic image matching services (services used by following subtypes)

6.2. Tie point extraction service

6.3. Control point transfer service

6.4. Elevation extraction service

6.5. Image pattern following services

6.6. Fiducial mark measurement service

6.7. Sample image matching services:

6.7.1. Object detection and location services

6.7.2. Object identification services

6.7.3. Object dimension determination services

6.7.4. Object classification services

7. Automated Image Understanding Services:

7.1. Pattern recognition services:

7.1.1. Object detection and location services

7.1.2. Object identification services

7.1.3. Object dimension determination services

7.1.4. Object classification services

7.2. Image comparison services

7.2.1. Pixel values difference determination services

7.2.2. Change detection services

7.2.3. Trend analysis services

7.2.4. Model-based differencing services

7.2.5. Negation (determination of origin) of changes services

8. Accuracy Conversion Services

8.1. Convert covariances to other forms:

8.1.1. Convert 3-D covariances to CE plus LE

8.1.2. Convert 2-D covariances to CE

8.1.3. Convert 1-D variance to LE

8.1.4. Convert 1-D variance to Standard Deviation

8.1.5. Convert 3-D covariances to Spherical Error

8.2. Convert other forms to covariances:

8.2.1. Convert CE plus LE to 3-D covariances

8.2.2. Convert CE to 2-D covariances

8.2.3. Convert LE to 1-D variance

8.2.4. Convert Standard Deviation to 1-D variance

8.2.5. Convert Spherical Error to 3-D covariances

9. Composite image exploitation services:
(Note: These higher level services use multiple lower level services)

9.1. Display window generation services:
(Note: Including image pan, zoom, rotate, and change histogram)

9.1.1. Monoscopic display window generation service

9.1.2. Stereoscopic display generation service

9.2. Object counting services

9.3. Feature extraction (automated) services

9.4. Synthetic image generation service

9.5. Intelligence data extraction services

9.6. Image registration services

10. Support metadata access services:

    10.1. Image geometry model metadata access service

    10.2. Spatial reference system (SRS) metadata access service

    10.3. Coordinate transformation metadata access service

    10.4. Image format metadata access service

    10.5. Values (of pixels) metadata access service

    10.6. Service capabilities metadata access service

    10.7. Service properties (or strategies) metadata access service

    10.8. Image geometry model transformation services

        10.8.1. Fit approximate image geometry model to existing image geometry model

        10.8.2. Convert image geometry model to different, mathematically equivalent model

> Editor's Note: In the service categorization above, the top level items (numbered 1 through 10) are the current categorization of image exploitation services to be used for further detailing. That is, OGC abstract specifications will be prepared for each listed service category. The first three listed categories are the highest priority for further detailing, in the listed order.
>
> The Coordinate Transformation WG is already developing abstract specifications for the first listed category "Ground Coordinate Transformation Services". The Image Exploitation Services SIG plans to develop abstract specifications for the second listed category "Image Coordinate Transformation Services". The "Image Modification Services" category partially overlaps the scope of the Simple Coverages RFP, and further development of abstract specifications for that category may be delayed until definitive responses to that RFP are received.

2.2.1. Notes on the image exploitation service taxonomy

Some notes on the above taxonomy and categorization:

1. This taxonomy favors similarity of the fundamental interfaces needed by different services (instead of similarities of services functions or use). Similarity of interfaces is more appropriate for development of multiple standard APIs to image exploitation services.

2. This taxonomy includes Automated Image Understanding Services (item 7) and Synthetic Image Generation Service (item 9.4), although these services are considered largely beyond the scope of this SIG. Many other services listed above under Composite Image Exploitation Services (item 9) are also largely beyond the scope of this SIG. These services are listed in this taxonomy in order to show how these higher level services are related to the image exploitation services within the scope of this SIG.

3. This taxonomy includes image coverage access services, although Coverages are a major concern of the Coverage Working Group. These coverage services are listed toward showing how this lower level service is related to and used by the image exploitation services within the scope of IES-SIG.

4. This taxonomy intends to include certain low level services that are used by higher level image exploitation services, although these lower level services may be partially the same for features and/or collections of features with geometry. For example, Ground Coordinate Transformation Services (item 1) are included.

5. This taxonomy intends to exclude high level services that are largely the same for features and/or collections of features with geometry. For example, geodata discovery and access services (Catalog services) are not included.

6. Most listed image exploitation services are also applicable to other grid coverage types, and some listed services are also applicable to non-grid coverage types. However, other grid and non-grid coverage types will need additional services, not included here.

7. Some of the listed services will have distinct sub-items (not all listed) using, for example, a) only one image or coverage and b) multiple images or coverages.

2.3. Uses of Other Services

Many of the image exploitation services listed above will use other listed services. For example, the Change Pixel Positions Services may use the Image-Ground Position Transformation Services. The service usage relationships are expected to produce a network of connected services, with some services being higher level and some being lower level in the service use network.

Figure 2-2 shows some of the expected usage relationships between the listed services, in the form of a UML class diagram. This diagram also shows possible usage of these services by mission-specific client applications, plus usage of the OpenGIS® Catalog and Coverage Services by these image exploitation services. To simplify this diagram, it does not show the multiplicities of the relationships shown; most relationship multiplicities could be many to many. This diagram also shows one box titled “Coordinate Transformation Services” that combines the “Ground Coordinate Transformation Services” plus the “Image Coordinate Transformation Services”.

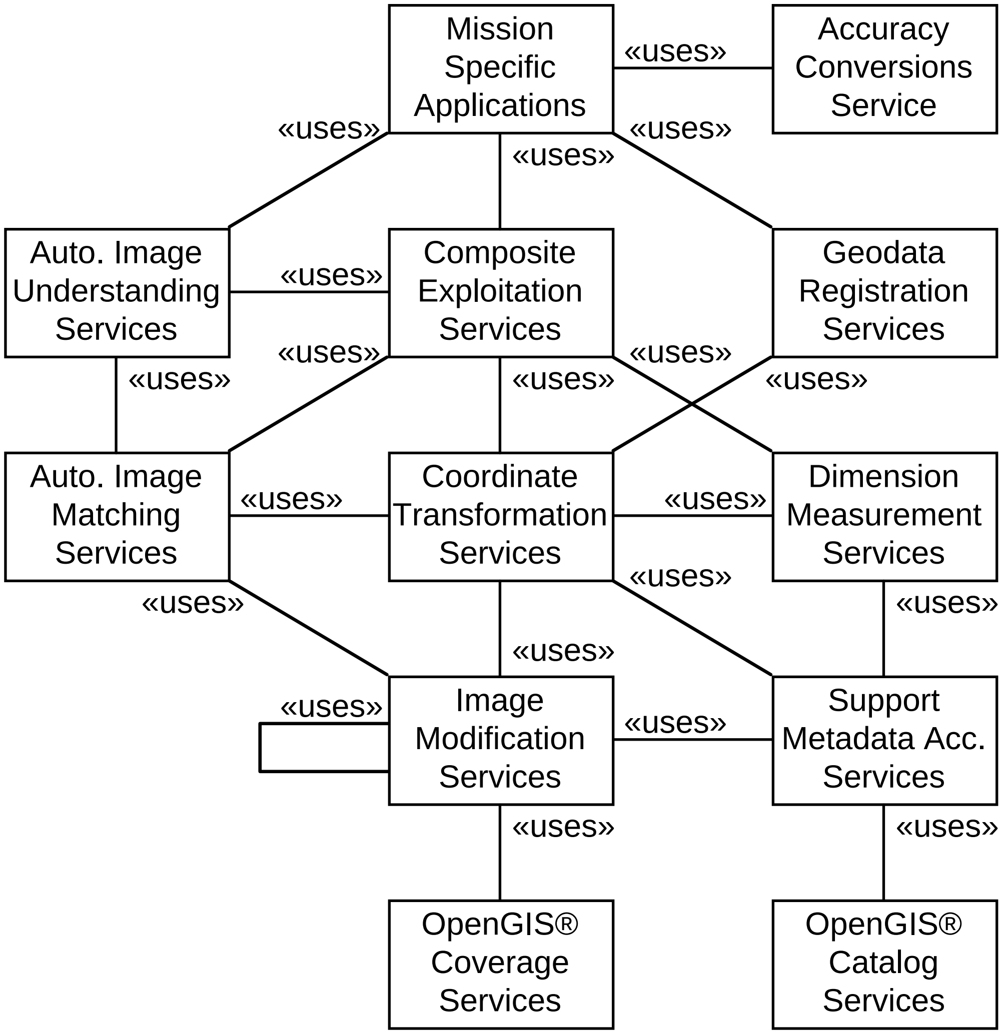

Figure 2-2. Possible Usage Relationships Among Image Exploitation Services

2.4. References for Section 2

[1] OpenGIS Abstract Specification, OpenGIS Project Documents 98-100 through 98-114, available through www as http://www.opengis.org/techno/specs.htm

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

3. Abstract Specification for Image Exploitation Services

The following subsections provide more detailed descriptions of most of the image exploitation service categories listed in the preceding taxonomy. These descriptions do not describe the contents and formats of the “needed data” and “result data” of each service. The “needed data” could alternately be called inputs, and the “result data” could alternately be called outputs. The “needed data” and “result data” of multiple services are often identical or similar, so the possible contents and formats of this data are discussed later in Section 4.

The image exploitation services will often use and produce metadata about the geospatial data that is manipulated. Metadata is the subject of the Metadata SIG and of Topic 11 of the Abstract Specification. To start to define service interactions with metadata, the “needed data” and “result data” items listed are often annotated with “(is metadata for ...)”.

3.1. Ground Coordinate Transformation Services

3.1.1. Function

The Ground Coordinate Transformation services convert ground position coordinates between different Spatial Reference Systems (SRSs). Some service types may have operations that convert the positions of multiple points (not just one point at a time).

3.1.2. Service subtypes

Service subtypes include but are not necessarily limited to the following:

3.1.2.1. Ground coordinate conversion (exact) services

3.1.2.1.1. Geodetic coordinate conversion services

3.1.2.1.2. Map projection conversion services

3.1.2.2. Ground coordinate transformation (approximate) services

3.1.2.2.1. Datum transformation services

3.1.2.2.2. Affine 2-D transformation service

3.1.2.2.3. General 2-D Polynomial transformation service

3.1.2.2.4. Polynomial 3-D transformation service

3.1.2.2.5. Vertical ground position transformation services

3.1.2.2.6. Other 3-D coordinate transformation services

3.1.2.2.7. Other 2-D horizontal ground position transformation services

3.1.2.3. Concatenated ground coordinate transformation services

These services may include two or more of the ground transformation and/or conversion services.

Note: Although different interfaces could be used for different numbers of input and output coordinates for the services listed below, we consider such separation undesirable.

3.1.2.3.1. 3-D to 3-D concatenated transformation

3.1.2.3.2. 2-D to 2-D concatenated transformation

3.1.2.3.3. 1-D to 1-D concatenated transformation

3.1.3. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Output ground position coordinates, in desired SRS

2. Partial derivatives of output position coordinates with respect to input position coordinates (optional, see note below)

3. Metadata for output position coordinates, including: (optional, see note below)

4. Output SRS definition (is metadata for output positions)

5. Absolute accuracy estimates for output position coordinates (is metadata for output positions)

6. Relative accuracy estimates for output position coordinates (is metadata for output positions)

Note: Result metadata is optionally returned to client software, depending on how the service is called. Similarly, partial derivatives are optionally returned to client software. The ability to produce result metadata and partial derivatives when requested are required capabilities of this service category.

3.1.4. Needed data

The data needed by these services (input data) includes, but are not limited to, the following:

1. Input ground position coordinates, in another SRS

2. Output SRS definition (is metadata for output positions)

3. Coordinate transformation parameters (optional) (is metadata for SRS or transformation)

4. Transformation accuracy estimates, for each SRS transformation (when output accuracy is needed) (is metadata for transformation)

5. Metadata for input position coordinates, including:

   5.1. Input SRS definition (is metadata for input positions)

   5.2. Absolute accuracy estimates for input position coordinates (when output absolute accuracy is needed) (is metadata for input positions)

   5.3. Relative accuracy estimates for input position coordinates (when output relative accuracy is needed) (is metadata for input positions)

3.1.5. Discussion

Ground Coordinate Transformation Services are considered a service category separate from the Image Coordinate Transformation Services (see Section 3.2) in order to limit the size of service categories. However, these two service categories require very similar interfaces, and they must be able to inter-operate easily. Specifically, the Concatenated Image Coordinate Transformation Services must be able to include individual or concatenated Ground Coordinate Transformation Services.

When a Ground Coordinate Transformation Service is needed, the corresponding service for the opposite direction will often also be needed. Instead of requiring a client to handle separate Ground Coordinate Transformation Services for each direction, it appears desirable to automatically link the corresponding Services for the two directions. This linking might be done in several ways, including:

- Have each Ground Coordinate Transformation Service provide transformations in both directions. Different service operations or an additional input to certain operations would be used to select which transformation direction is requested.

- Provide a Ground Coordinate Transformation Service with an additional operation to obtain the reverse direction Service (or to obtain all the metadata needed by such a service)

Editors note: These Ground Coordinate Transformation Services roughly correspond to the Geospatial Coordinate Transformation Services now in Topic Volume 12 (Services Architecture), and to the transformations being specified in Topic Volume 2 (Coordinate Systems and Transformations).

3.2. Image Coordinate Transformation Services

3.2.1. Function

The Image Coordinate Transformation services, alternatively called Image Geometry Model services, describes a group of services that convert image position coordinates between different Spatial References Systems (SRSs). Some service types may have operations that convert the positions of multiple points (not just one point at a time).

3.2.2. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Output point position coordinates, in desired SRS

2. Partial derivatives of output position coordinates with respect to input position coordinates (optional, see note below)

3. Metadata for output position coordinates, including: (optional, see note below):

3.1. Output SRS definition (is metadata for output positions)

3.2. Absolute accuracy estimates for output position coordinates (is metadata for output positions)

3.3. Relative accuracy estimates for output position coordinates (is metadata for output positions)

Note: Result metadata is optionally returned to client software, depending on how the service is called. Similarly, partial derivatives are optionally returned to client software. The ability to produce result metadata and partial derivatives when requested are required capabilities of this service category.

3.2.3. Needed data

The data needed by these services (input data) includes, but are not limited to, the following:

1. Input point position coordinates, in another SRS

2. Output SRS definition (is metadata for output positions)

3. Coordinate transformation parameters (optional) (is metadata for SRS or transformation)

4. Transformation accuracy estimates, for each SRS transformation (when output accuracy is needed) (is metadata for transformation)

5. Elevation data (for monoscopic image to ground) (could be considered metadata for an image?)

6. Elevation accuracy estimates (when output accuracy is needed) (is metadata for elevation data)

7. Metadata for input position coordinates, including:

7.1. Input SRS definition (is metadata for input positions)

7.2. Absolute accuracy estimates for input position coordinates (when output absolute accuracy is needed) (is metadata for input positions)

7.3. Relative accuracy estimates for input position coordinates (when output relative accuracy is needed) (is metadata for input positions)

3.2.4. Service subtypes

3.2.4.1. Image-ground position transformation services

3.2.4.1.1. Ground to image position transformation service (3-D to 2-D)

3.2.4.1.2. Stereoscopic images to ground position transformation service (multiple 2-D to one 3-D)

3.2.4.1.3. Monoscopic image plus elevation to ground position transformation service (2-D plus elevation to 3-D)

3.2.4.1.4. Monoscopic image plus other data to ground position transformation service (2-D plus other data to 3-D). (This other data might include laser profiling or radar range data.)

3.2.4.2. Image position transformation services (2-D to 2-D)

3.2.4.2.1. Polynomial transformation service

3.2.4.2.2. Image to rectified image position conversion service

3.2.4.2.3. Rectified image to image position conversion service

3.2.4.3. Concatenated image coordinate transformation services

These services include two or more of the above image transformations plus ground coordinate transformations and conversions.

Note: Although different interfaces could be used for different numbers of input and output coordinates, as listed in services below, we consider such separation undesirable.

3.2.4.3.1. 3-D to 2-D concatenated transformation (ground to image)

3.2.4.3.2. 2-D to 3-D concatenated transformation (image to ground)

3.2.4.3.3. 2-D to 2-D concatenated transformation (image to image)

3.2.5. Discussion

Image Coordinate Transformation Services are considered a service category separate from the Ground Coordinate Transformation Services (as discussed in the preceding subsection) in order to limit the size of service categories. However, these two service categories require very similar interfaces, and they must be able to inter-operate easily. Specifically, the concatenated image coordinate transformation services (see service subtype 3 above) must be able to include individual or concatenated Ground Coordinate Transformation Services.

When an Image Coordinate Transformation Service is needed, the corresponding Service for the opposite direction will often also be needed. Instead of requiring a client to handle separate Image Coordinate Transformation Services for each direction, it appears desirable to automatically link the corresponding Services for the two directions. This linking might be done in several ways, including:

- Have each Image Coordinate Transformation Services provide transformations in both directions. Different service operations or an additional input to certain operations would be used to select which transformation direction is requested.
- Provide an Image Coordinate Transformation Service with an additional operation to obtain the reverse direction Service (or to obtain all the metadata needed by such a service)

Editors note: These Image Coordinate Transformation Services roughly correspond to parts of the Image Geometry Model Services and the Geospatial Coordinate Transformation Services now in Topic Volume 12 (Services Architecture).

3.3. Imaging Time Determination Service

Technical Note: For certain purposes these services could be considered subsidiary to (i.e., a specialization of) the Image Coordinate Transformation Services (Section 3.2). They are described separately here because they need somewhat different interfaces, and the service interfaces may be separately specified by the OGC.

3.3.1. Function

These services are used to determine the imaging time of points in an image. For a “frame” type of image, all points are imaged at the same time. For pushbroom, whiskbroom, panoramic, SAR, and other types of images, different points in one image are imaged at somewhat different times. The imaging time differences within one image can be important for some image exploitation purposes, such as estimating the velocity of imaged objects.

3.3.2. Service subtypes

Services in this category include, but are not limited to, the following:

3.3.2.1. Determine imaging time for one or more image positions

3.3.3. Results Data

The data resulting from these services (output data) includes, but are not limited to, the following:

1. Imaging times

2. Metadata for imaging times, including: (optional, see note below)

    2.1. Temporal SRS definition (is metadata for output times)

    2.2. Absolute accuracy estimates for imaging times (is metadata for output times)

    2.3. Relative accuracy estimates for imaging times (is metadata for output times)

> Note: Result metadata is optionally returned to client software, depending on how the service is called. The ability to produce result metadata when requested is a required capability of the service.

3.3.4. Needed data

The data needed by these services (input data) includes, but are not limited to, the following:

1. Image position coordinates

2. Output temporal SRS definition (is metadata for output times)

3. Temporal SRS transformation parameters (optional) (is metadata for temporal SRS or transformation)

4. Temporal transformation accuracy estimates (when output accuracy is needed) (is metadata for temporal transformation)

5. Metadata for input position coordinates, including

    5.1. Input SRS definition (is metadata for input positions)

    5.2. Absolute accuracy estimates for input position coordinates (when output absolute accuracy is needed) (is metadata for input positions)

    5.3. Relative accuracy estimates for input position coordinates (when output relative accuracy is needed) (is metadata for input positions)

3.3.5. Discussion

Specification and implementation of this imaging time determination service probably depends on specification of temporal reference systems. Imaging time determination also depends on the temporal part of image geometry models. Complete specification of temporal reference systems has been put off for future work by the OGC. Therefore, complete specification and implementation of this imaging time determination service may have to be delayed.

> Editor's Note: This Imaging Time Determination Services may be notionally categorized as a subtype of Image Coordinate Transformation Services because time can be considered as another dimension of a point coordinate. Furthermore, the data needed to determine imaging time is closely related to the data needed to transform image positions.

3.4. Image Modification Services

3.4.1. Function

The Image Modification Services produce modified version of images, providing access to all or selected sections of the modified image. Most of these services modify one image. However, some services must or can combine two or more images. Some of these service types also allow a client to change a selected section of the modified image, with the corresponding changes being made to the original image(s).

3.4.2. Service Subtypes

Services in this category include, but are not limited to, the following:

3.4.2.1. Change pixel values services

Editor's Note: Includes previously defined simple pixel manipulation services.

3.4.2.1.1. Tone modification services

1. Tonal Transfer Curve (TTC) service

2. Dynamic Range Adjustment (DRA) service

3. Histogram Equalization service

3.4.2.1.2. Spatial filtering (or convolution) services

1. Linear filtering service

2. Edge extraction services

3. Other non-linear filtering services

4. Artifact correction services

3.4.2.1.3. Pixel (multi-band or multi-image) classification services

3.4.2.1.4. Image segmentation services

3.4.2.1.5. Band and image combination services

3.4.2.1.6. Other image enhancement services

3.4.2.1.7. Simulate non-idealities services

1. Simulate imaging conditions non-idealities services (e.g., haze)

2. Simulate image sensor non-idealities services (e.g., detector calibration errors)

3. Simulate illumination direction change services

3.4.2.1.8. Histogram generation service

3.4.2.1.9. Fourier analysis service

3.4.2.1.10. Other frequency domain services

3.4.2.1.11. Graphical overlay application service

3.4.2.1.12. Grid overlay generation service

3.4.2.2. Change pixel positions services

3.4.2.2.1. Pixel resampling service (service used by following subtypes)

3.4.2.2.2. Polynomial transformation warping service

3.4.2.2.3. Computer graphics warping services (including splines, piece-wise transformations)

3.4.2.2.4. Image rectification service

3.4.2.2.5. Orthorectification service (including orthophoto stereomate generation)

3.4.2.2.6. Image mosaicking service

3.4.2.2.7. Perspective scene generation service

3.4.2.3. Change image data format services

Technical Note: Includes or uses Image Coverage Access Services.

3.4.2.3.1. Image section retrieval services

1. Single pixel retrieval service

2. Patch (or rectangular window) retrieval service

3. Polygon area (area-of-interest, AOI) retrieval service

3.4.2.3.2. Image section replacement services

1. Single pixel replacement service

2. Patch (or rectangular window) replacement service

3. Polygon area (area-of-interest, AOI) replacement service

3.4.2.3.3. Tiling change services

3.4.2.3.4. Reduced resolution generation service

3.4.2.3.5. Increased resolution estimation (or creation) services

3.4.2.3.6. Image compression and decompression services:

1. Lossy compression services

2. Lossless compression services

3.4.2.3.7. Composite image modification services

Includes two or more of the above image modifications. (Note: A composite modification is a single service that combines or concatenates what would otherwise be multiple separate services.)

Editor's Note: This service category may be too large, and it may have to be split into two or more categories. For example, the "Change Pixel Values Services" could be separated from the "Change Pixel Positions Services". These services are listed as one category here because of the commonality of required interfaces.

3.4.3. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Modified image pixels, for entire image or selected section of image

2. Metadata for modified image pixels, including: (optional, see note)

3. Modified image SRS definition (is metadata for output image)

4. Actual image modifications identification and parameters (is lineage metadata for output image)

Note: Result metadata is optionally returned to client software, depending on how the service is called. The ability to produce result metadata when requested is a required capability of the service.

3.4.4. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Existing image pixels, for each image used

2. Modified image SRS definition (if changing pixel positions) (is metadata for output image)

3. Selection of desired image modifications (is metadata for modified image)

4. Values of parameters required and useful to control modification processes (sometimes called strategy parameters) (is metadata for adjustment process)

5. Selection of desired image section (is metadata for image section)

6. Metadata for existing image pixels, including:

7. Input image SRS definition (is metadata for input image)

8. Input image pixel formats (is metadata for input image)

3.4.5. Discussion

The image SRS definition input and output are required only when pixel positions are modified. However for interface generality, this input and output might be included in all cases, with the output being the same as the input when pixel positions are not modified.

When an Image Modification Service (indirectly or directly) includes one or more Change Image Pixel Position Services, it will often be necessary to perform the corresponding Image Coordinate Transformation, as discussed in Section 2.2 above. That is, it may be necessary to take point positions in the modified image and determine the corresponding point positions in the original image. Alternately, it may be necessary to take point positions in the original image and determine the corresponding point positions in the modified image. Furthermore, it may be necessary to take point positions in the modified or original image and determine the corresponding point positions in any desired ground coordinate SRS.

Instead of requiring the software to handle one or more separate Image Coordinate Transformation Services for an Image Modification Service, it appears desirable to (perhaps optionally) automatically link a single Image Modification Service to the corresponding Image Coordinate Transformation Services. This linking might be done in several ways, including:

- Provide a service that has the (standard) interfaces for both Image Modification and Concatenated Image Coordinate Transformation services
- Provide an Image Modification Service with an additional operation to obtain the corresponding Image Coordinate Transformation Service (or to obtain all the metadata needed by such a service)

When an Image Modification Service (indirectly or directly) uses more that one source image, there can be a different Coordinate Transformation for each source image. When this occurs, it appears necessary to include an input to some operations that specifies which source image is being used.

3.5. Dimension Measurement Services

3.5.1. Function

The Dimension Measurement Services compute dimensions of objects visible in an image or other geodata. An alternative name for this service category is “Image Mensuration Services.”

It is assumed that dimensions are required in a selected SRS, often a **project world** SRS. It is further assumed that dimensions are computed from positions measured in an (unrectified) image or other SRS. In most cases, dimension computation requires access to the (approximate) elevation of at least one point. (Possible forms of elevation data are discussed in Section 3.6.)

3.5.2. Service Subtypes

Services in this category include, but are not limited to, the following:

3.5.2.1. Line segment dimensions services:

3.5.2.1.1. Compute horizontal length and angle clockwise from North of a line segment, from one point to a second point

3.5.2.1.2. Compute 3-D length and direction angles of a line segment, from one point to a second point

3.5.2.2. Multi-segment line length service:

3.5.2.2.1. Compute length of multi-segment line feature or real world object, from sequence of vertices representing spatial position of that line

3.5.2.3. Area dimensions services:

3.5.2.3.1. Compute area and perimeter of area feature or real world object, from sequence of vertices representing the polygon boundary of that area

3.5.2.3.2. Compute size, orientation, and center position of a standard geometrical shape, from a sequence of points on the perimeter of that shape. (The standard geometrical shapes are *usually horizontal or vertical in the project world SRS. A variety of different shapes could be supported, including rectangle, square, ellipse, circle, parallelogram, and more complex shapes.)*

3.5.2.1. Height dimension service:

3.5.2.1.1. Compute height of a vertical real-world object (such as a pole or building), from one point on the image of the top and a second point on the image of the base. (The real-world object is assumed to be vertical in the project world SRS.)

3.5.2.1.2. Compute height of a vertical real-world object (such as a pole or tower), from one point on the image of the top and a second point on the image of the shadow of the first point. (The real-world object is assumed to be vertical in the project world SRS. This computation requires access to the illumination direction, and assumes that the top of the shadow falls on a surface at the same elevation as the base of the real-world object.)

3.5.2.2. Volume dimension service:

3.5.2.2.1. Compute volume of a solid features using its shell, from a sequence of vertexes for each facet of the shell. (This capability requires the ability to record features with volume geometries. Handling of volume features has been put off for future work by the OGC. Therefore, complete specification and implementation of this Volume dimension service may have to be delayed.)

3.5.2.2.2. Compute cut and fill volumes between two different elevation surfaces, specified by a digital terrain matrix, regular triangulated network, or triangulated irregular network.

3.5.2.3. Temporal dimension service:

3.5.2.3.1. Compute time difference between two points with known time coordinates.

3.5.2.3.2. Compute velocity of same object imaged at two different points and times, in the same or different images. The object could be assumed to travel in a straight line between these two points, or to travel along a defined path.

Technical Note: Specification and implementation of the Temporal dimension service depends on the ability to represent time in point coordinates. Specification and implementation of time representation probably depends on specification of temporal reference systems. Complete specification of time representation and of temporal reference systems has been put off for future work by the OGC. Therefore, complete specification and implementation of this Temporal dimension service may have to be delayed.

3.5.3. Results

The data resulting from these services (output data) includes, but are not limited to:

1. Values of one or more computed dimensions, in desired SRS

2. Dimension accuracy estimates, in output dimension SRS (optional) (is metadata for dimensions)

3. The possible output dimension data types and units include:

3.1. Distance (in ground coordinate units)

3.2. Area (in ground coordinate units squared)

3.3. Angle (in degrees, probably measured clockwise from North)

3.4. Position Coordinates (in ground coordinate units)

3.5. Volume (in ground coordinate units cubed, or in the product of the ground coordinate units in the three axes)

3.6. Time Difference (in time units)

3.7. Velocity (in distance units divided by time units)

3.5.4. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Point position coordinates, in any SRS

2. Selection of desired dimensions

3. Illumination direction, azimuth and elevation angles (when computing height from shadow or layover) (is metadata for image)

4. Position accuracy estimates for input position coordinates, relative or absolute (when dimension accuracy is needed) (is metadata for input positions)

5. Output SRS definition (is metadata for output dimensions)

6. Input SRS definition (is metadata for input positions)

7. Coordinate transformation parameters (optional) (is metadata for SRS or transformation)

8. Elevation data (for monoscopic image to ground) (could be considered metadata for an image?)

9. Elevation accuracy estimates (when elevation is input and output accuracy is needed) (is metadata for elevation data)

Technical Note: This service must use an Image Coordinate Transformation Service when the input position coordinates SRS is not the desired ground position SRS, and coordinate transformation is thus required.

3.6. Geodata Registration Services

3.6.1. Function

The Geodata Registration Services change the estimated SRS of one or more images, or other geospatial datasets, to better match other geospatial datasets.

Change SRS by adjusting the parameters of an existing SRS or of a transformation between two SRSs. (Some SRSs are defined by the transformation from another specified SRS.) When a transformation is adjusted, usually only one transformation in a chain of existing transformations is adjusted. The adjusted transformation may initially be a null transformation inserted in the chain for the purpose of being adjusted.

3.6.2. Service Subtypes

3.6.2.1. Adjust one SRS (Spatial Reference System) to another SRS.

The adjusted SRS is usually for one image or other dataset, but could be the SRS for multiple datasets.

3.6.2.2. Adjust multiple SRSs to each other (but not adjust to a fixed SRS)

3.6.2.3. Adjust multiple SRSs to a fixed SRS and to each other

3.6.3. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Adjusted parameters of transformation between SRSs, for each adjusted transformation (is metadata for image or other dataset)

2. Transformation accuracy estimates, for each adjusted transformation (optional) (is metadata for transformation)

3.6.4. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Positions of same point in two or more SRSs, for multiple points

2. Selection of transformations and parameters to be adjusted

3. Parameters of existing transformations between SRSs, for each SRS in which a position is provided (is metadata of point position SRSs), including:

3.1. Adjustable transformations

3.2. Non-adjustable transformations

4. Position accuracy estimates for input position coordinates (is metadata for input positions):

4.1. Absolute accuracy estimates, of each point (required)

4.2. Relative accuracy estimates, between points (optional)

5. Transformation accuracy estimates, for parameters of each adjustable transformation (optional) (is metadata for transformation)

6. Transformation accuracy estimates, for each non-adjustable transformation, or for complete SRS definition of each SRS (optional) (is metadata for SRS)

7. Values of parameters required and useful to control adjustment process (sometimes called strategy parameters) (is metadata for adjustment process?)

Technical Note: This service must use an image coordinate transformation service, and/or a ground coordinate transformation service, to compute corresponding positions in different SRSs. That service must also be used to compute partial derivatives of output coordinates with respect to input coordinates. For adjustable parameters, extensions to those services are needed to compute partial derivatives of position coordinates with respect to the adjustable parameters.

3.6.5. Discussion

Adjustments are often done by minimizing the mean square of the weighted residual errors in fitting an input set of point position data. The weighted residual errors in fitting measured transformation parameters can also be included. The weights are usually inversely proportional to the error estimates for each point position or transformation parameter. For such least-square adjustment, there must be more known values than adjusted values, sometimes up to twice as many known values.

The position of each point must be previously determined in two or more different SRSs. For flexibility, this service does not include measuring the positions of points in images or other datasets with different SRSs, for example, “Tie Point Extraction” and “Control Point Transfer” services (see Section 3.6.5). A higher level composite service could combine registration with measuring the positions of points in images or other datasets, see item 9.6 in Section 1.

3.6.6. Related Services

Automated Image Matching Services

3.7. Automated Image Matching Services

3.7.1. Function

The Automated Image Matching Services determine matching positions in two or more images, using (partially) automated image comparison methods. Some manual assistance could also be allowed.

The multiple images may be of the same ground area, or of different ground areas with similar appearances.

These services match small or larger areas in the different images (not matching single pixels, which is impractical).

3.7.2. Service Subtypes

Services in this category include, but are not limited to, the following:

3.7.2.1. Basic image matching services (services used by following subtypes):

3.7.2.1.1. Correlation matching service

3.7.2.1.2. Least-squares matching service

3.7.2.2. Tie point extraction service

3.7.2.3. Control point transfer service

3.7.2.4. Elevation extraction service

3.7.2.5. Image pattern following services

3.7.2.6. Fiducial mark measurement service

3.7.2.7. Sample image matching services

3.7.2.7.1. Object detection and location services

3.7.2.7.2. Object identification services

3.7.2.7.3. Object dimension determination services

3.7.2.7.4. Object classification services

3.7.3. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Feature(s) with geometry. Possible feature geometries include:

    1.1. Single point

    1.2. Set of points

    1.3. Grid of points

    1.4. Linear feature geometry

    1.5. Area feature geometry

    1.6. Volume feature geometry

2. Metadata for output feature geometry, including: (optional, see note)

    2.1. Measures of quality of image match

    2.2. Absolute accuracy estimates for output feature geometry

    2.3. Relative accuracy estimates for output feature geometry

3.7.4. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Image pixels, for each image to be used, often a specified section of a larger image

2. Output SRS definition (is metadata for output feature)

3. Input image SRS definition (is metadata for input image)

4. Selection of desired image matching service

5. Values of parameters required and useful to control matching process (sometimes called strategy parameters) (is metadata for matching process?)

6. Approximate feature with geometry (optional)

7. Input feature SRS definition (optional) (is metadata for input feature)

8. Position accuracy estimates for input feature geometry (optional) (is metadata for input feature)

    8.1. Absolute accuracy estimates (when absolute accuracy is needed)

    8.2. Relative accuracy estimates (when relative accuracy is needed)

9. Elevation data (for monoscopic image to ground) (could be considered metadata for an image?)

10. Elevation accuracy estimates (when elevation is input and output accuracy is needed) (is metadata for elevation data)

3.8. Accuracy Conversion Services

3.8.1. Function

The Accuracy Conversion Services convert position accuracy estimates between error covariance matrix form and Circular Error (CE) plus Linear Error (LE) or other forms.

These accuracy conversions are also applicable to linear dimensions and perhaps other accuracy estimates.

3.8.2. Service Subtypes

Services in this category include, but are not limited to, the following:

3.8.2.1. Convert covariance matrices to other forms

3.8.2.1.1. Convert 3-D covariances to CE plus LE

3.8.2.1.2. Convert 2-D covariances to CE

3.8.2.1.3. Convert 1-D variance to LE

3.8.2.1.4. Convert 1-D variance to Standard Deviation

3.8.2.1.5. Convert 3-D covariances to Spherical Error

3.8.2.2. Convert other forms to covariance matrices

3.8.2.2.1. Convert CE plus LE to 3-D covariances

3.8.2.2.2. Convert CE to 2-D covariances

3.8.2.2.3. Convert LE to 1-D variance

3.8.2.2.4. Convert Standard Deviation to 1-D variance

3.8.2.2.5. Convert Spherical Error to 3-D covariances

3.8.3. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. Accuracy estimates in desired form (is metadata for some point positions)

2. Confidence level(s) for output CE and LE values (is metadata for CE and LE values?)

3.8.4. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Accuracy estimates in another form (is metadata for same point positions)

2. Selection of accuracy estimate form desired

3. Confidence level(s) for input CE and LE values (is metadata for CE and LE values?)

4. Accuracy conversion parameters (is metadata for accuracy conversions?)

3.8.5. Discussion

Both absolute and relative accuracy estimates can be separately converted by these services.

Some cells of a covariance matrix may be unknown, and unknown cells must be handled in an appropriate manner.

When converting most other forms of accuracy data to covariance matrices, correct values will not be known for some covariance matrix cells. Specifically, the off-diagonal cells for covariances between coordinates will not be known. As specified in Abstract Specification Topic 9: Quality, the values of these covariance matrix cells should be null or missing. (Alternately, these covariances values would be assumed to be zero.)

3.9. Metadata Access Services

3.9.1. Function

The Metadata Access Services retrieve or modify desired metadata, converting its format when needed.

3.9.2. Service Subtypes

Services in this category include, but are not limited to, the following:

3.9.2.1. Image geometry model metadata access service

3.9.2.2. Spatial reference system (SRS) metadata access service

3.9.2.3. Coordinate transformation metadata access service

3.9.2.4. Image format metadata access service

3.9.2.5. Values (of pixels) metadata access service

3.9.2.6. Service capabilities metadata access service

3.9.2.7. Service properties (or strategies) metadata access service

3.9.2.8. Support Metadata Retrieval Services

3.9.2.8.1. Result Data:

1. Metadata (or service using metadata) (is metadata)

3.9.2.8.2. Needed Data:

1. Image or dataset identification (is metadata for dataset)

2. Selection of desired metadata (or of service using metadata)

3. Selection of desired metadata format

3.9.2.9. Support Metadata Modification Services

3.9.2.9.1. Result Data:

1. Success or failure of metadata modifications

3.9.2.9.2. Needed Data:

1. Modified metadata (or service having modified metadata)

2. Image or dataset identification (is metadata for dataset)

3. Specification of input metadata format (is part of metadata?)

4. Selection of metadata to be modified

3.9.3. Discussion

Technical Note: Services 3.9.2.8 and 3.9.2.9 are alternatives to the preceding services that combine Metadata Access Services with the services that use each type of metadata.

Metadata retrieval and modification services have different interfaces, as outlined above, although they might be implemented as different operations of a single service.

3.10. Image Geometry Model Transformation Services

3.10.1. Function

The Image Geometry Model Transformation Services produce a different geometry model for an image, or metadata for a different image geometry model.

3.10.2. Consequences

There are many different possible geometry models for an image, with different properties. For example, a rigorous geometry model can be accurately adjusted (see Section 2.5), but has high computation requirements. On the other hand, a “real-time” geometry model has lesser computation requirements, but cannot be accurately adjusted. Transformation from a rigorous geometry model to a corresponding “real-time” geometry model is then sometimes required. (Transformation from a “real-time” geometry model to a rigorous geometry model is usually not possible or practical.)

These Image Geometry Model Transformation Services are described here because they are similar to Metadata Access Services. These Image Geometry Model Transformation Services support the Image Coordinate Transformation Services. However, these Image Geometry Model Transformation Services have significantly different interfaces.

3.10.3. Service Subtypes

Services in this category include, but are not limited to, the following:

3.10.3.1. Fit approximate image geometry model to point positions computed using existing image geometry model

3.10.3.2. Convert image geometry model to different, mathematically equivalent model, by converting geometry parameters of existing image geometry model

3.10.4. Results Data

The data resulting from these services (output data) includes, but are not limited to:

1. New image geometry model, for entire image or selected section of image (is modified metadata for image)

2. Metadata for new image geometry model, including:

    2.1. Absolute accuracy estimates for new model (is metadata for new model)

    2.2. Relative accuracy estimates for new model (is metadata for new model)

    2.3. Modified image SRS definition (is metadata for new model)

    2.4. Identification of applicable image section (is metadata for new model)

    2.5. Model fitting error estimates (is metadata for new model)

Technical Note: These services should always return result metadata to client software (result metadata is not optional).

3.10.5. Needed data

Inputs (needed data) to these services include, but are not limited to, the following:

1. Existing image geometry model (is metadata for image)

2. Desired accuracy of geometry model transformation

3. Values of parameters required and useful to control transformation processes (sometimes called strategy parameters) (is metadata for transformation process)

4. Selection of desired image section (is metadata for new model)

5. Metadata for existing image geometry model, including

    5.1. Absolute accuracy estimates for model (is metadata for model)

    5.2. Relative accuracy estimates for model (is metadata for model)

    5.3. Existing image SRS definition (is metadata for model)

4. Well Known Types and Structures

This section describes in broad "notional" terms the contents and use of the "needed data" and "result data" elements for the services described in the previous section. The "needed data" can alternately be called inputs, and the "result data" can alternately be called outputs. This section discusses various data categories, recognizing that the "needed data" and "result data" of multiple services are often identical or similar. Some of these data descriptions use the ISO (and CORBA) standard Interface Definition Language (IDL) to more concisely convey their scope and use. A brief summary of the IDL data types and structures is also included.

More detailed specification of "well known types" and "well known structures" for image exploitation is left to the respective service descriptions planned in other topic volumes of the OpenGIS® Abstract Specification.

4.1. Metadata

The image exploitation services will often use and produce metadata about the geospatial data that is manipulated. Metadata is the subject of the Metadata SIG and of Topic 11 of the Abstract Specification. To start to define service interactions with metadata, inputs and outputs listed in Section 3 are often annotated with "(is metadata for ...)".

Several aspects of metadata have already been standardized, as discussed below, and thus do not need to be standardized as part of defining standard interfaces to various image exploitation services. Indeed, these aspects of metadata organization should be the same for all OpenGIS® services.

The draft ISO Metadata Standard, 15046-15, specifies the logical organization to be used for metadata, including both standard and custom metadata. Related metadata "elements" are grouped into metadata "entities" (including metadata "sections"). Each metadata entity (or section) contains a defined set of metadata elements and/or a set of lower level metadata entities. Each metadata element, entity, and section has a name and a definition.

The current version of Abstract Specification Topic 11: Metadata requires use of the ISO metadata concepts and terminology. In addition, Topic 11 provides object-oriented notation for ISO-structured metadata. All metadata entities (and sections) comprise one abstract class, and each type of metadata entity (and section) is a concrete subclass. Each metadata entity (or section) subclass contains a set of metadata elements and/or lower level entities. The included metadata element names and corresponding values are captured as attributes of the object subclass.

In Topic 11, a metadata set is a concrete class where each metadata set object contains a collection of metadata entity objects, serving as metadata sections. Each OpenGIS® feature collection and/or individual feature is directly related to one metadata set object.

The draft ISO Metadata Standard, 15046-15, also specifies the names, definitions, data types, units, etc. for many metadata elements in many metadata entities. Some of these metadata elements and entities are mandatory and some are optional. In many cases, an image exploitation service input or output in Section 3 that is marked "(is metadata for ...)" is all or most of one ISO metadata entity. Table 4-1 lists various service inputs and outputs with the exactly or approximately corresponding ISO metadata entities.

Image Exploitation Service Input or Output	**ISO Metadata Name**	
	Section	**Entity**
Ground position SRS definition, Coordinate transformation parameters, Adjusted parameters of transformation between SRSs	Reference system information	Spatial reference by coordinates (and lower level entities)
Illumination direction, azimuth and elevation angles	Spatial data representation information	Image spatial representation information (part of entity)
Image or dataset identification	Identification information	Identification Citation, Image identification information
Imaging times, Accuracy estimates for imaging times	Identification information	Temporal extent (in Extent information)
Temporal SRS definition	Reference system	Temporal reference system information

	information	
Specification of metadata format	Metadata reference information	Metadata standard information, Metadata extension information

Table 4-1. ISO Metadata Used as Service Inputs and Outputs

4.2. Image Pixels

As listed in Section 3, image pixels are inputs and outputs of several image exploitation service categories. In addition to transferring pixel values, the size of the pixel grid must be transferred, plus the sequencing scheme used when transferring pixel values. Responses to the Simple (or grid) Coverages RFP are expected to specify standard formats for transferring image pixels and other grid data, as inputs and outputs to Coverage access operations. This document assumes that these grid coverage formats can be used to transfer image pixels for image exploitation services inputs and outputs.

4.3. Desired Image Section

The desired image section is also an input or output of several image exploitation service categories. The location and size of the desired image section must be specified, within a larger image (or set of image pixels). Responses to the first (or grid) Coverages RFP are also expected to specify standard formats for specifying the desired image section, as inputs and outputs to Coverage access operations. This document assumes that this image section specification format can be used for image exploitation services.

Alternately, the desired image section could be specified using an area feature geometry, such as specified in the three Simple Features implementation specifications that have been accepted by the OGC. We assume this area feature geometry would be in 2-D image coordinates, not 3-D or 2-D ground coordinates.

If the desired image section is a rectangle in image space, such a rectangle could be specified by the pixel position of one corner, plus the pixel section width and height. Using this approach, an Image Section data type defined using ISO standard IDL data types and structures is:

```
// Type: Image Section, rectangular section of an image
      struct ImageSection {
         long corner_column; // Smallest pixel column number
         long corner_row;    // Smallest pixel row number
         long width;         // Number of image pixel columns
         long height;        // Number of image pixel rows
         };
```

4.4. Point Position Coordinates

Point position coordinates are also inputs and outputs of several image exploitation service categories. Such a point position requires specifying the values of three, two, or one coordinates. All three OpenGIS® accepted implementation specifications for Simple Features include data formats for point positions in two (or three, TBR) coordinates. (We are referring to the vertices of feature geometries, not to point geometries.) That format is a data structure containing two (or three, TBR) floating point numbers. The modification of this data format to three or one coordinate is obvious.

(Note: The SRSs used for point position coordinates are listed as separate service inputs and outputs, and are discussed in Table 1 of Section 3.1.)

4.5. Position Accuracy Estimates

Absolute and relative position accuracy estimates are also inputs and outputs of several image exploitation service categories. The accuracy inputs and outputs are often optional, needed by operations only when accuracy output data is desired by a client program or user. Several alternative forms of accuracy data could be used. However, Abstract Specification Topic 9: Quality specifies that accuracy be recorded as covariance matrices.

As discussed in Section 2.8 of Topic 9, detailed accuracy information can be recorded using a covariance matrix, sometimes called a variance-covariance matrix. For the three ground coordinates of one point, a covariance matrix is a 3 by 3 matrix, with the matrix rows and columns each corresponding to the three coordinates. For just the two horizontal ground coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two horizontal coordinates. Similarly, for two image coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two image coordinates.

The covariance matrix cells contain the expected average values of the product of the error in the matrix row coordinate times the simultaneous error in the matrix column coordinate. For absolute accuracy, the diagonal matrix cells contain the error variances of the corresponding ground coordinates, or the squares of the standard deviations. The off-diagonal cells contain the covariances between the errors in the corresponding ground coordinates; these covariances will be zero when the errors in different coordinates are not statistically correlated. All covariance matrices are symmetrical, meaning that the same cell values appear on both sides of the diagonal cells.

Covariance matrices can be used to record absolute and/or relative accuracies. A covariance matrix for the relative accuracy between two points uses the three (or two) coordinates of one point for matrix rows and the three (or two) coordinates of the second point for matrix columns. A complete covariance matrix for N specific points would contain 3N rows and 3N columns.

When other forms of accuracy data are desired by a user, such as Circular Error (CE) and Linear Error (LE), they can be converted from (or to) covariance matrices. (Please see Sections 2.4 through 2.7 of Topic 9 for definitions of CE, LE, and other forms of accuracy data.) Such accuracy conversion is the purpose of the Accuracy Conversion Services, as discussed in Section 2.7 of this document. CE and LE can each be transferred as a single precision floating point number, as can the confidence probability associated with each CE and LE.

This document assumes that accuracy will always be specified in OpenGIS® interfaces in units of meters or meters-squared, as specified in Abstract Specification Topic 9: Quality. Alternately, the units used for accuracy values must be specified.

4.5.1. Covariance Matrix Data Structures

A covariance matrix may not have known values for all matrix cells, so the data structure used should allow some cells to have null or missing values. One possible way to transfer a potentially incomplete covariance matrix is to use a list, or one-dimensional array, of simple data structures. This list will contain a simple data structure for each known and unique valued covariance matrix cell. Each simple data structure will contain a covariance matrix cell identifier and the corresponding cell value. Each matrix cell identifier could consist of two characters, each character designating one of the matrix cell indices. The cell value could be a single precision floating point value.

Using this approach, a set of accuracy data types can be defined. Such a set defined using ISO standard IDL data types and structures is:

```
// Type: Matrix Cell, of a covariance matrix
      struct MatrixCell {
         string <2>   axes;   // Axes of covariance matrix
         float        value;  // Units: Meters squared
         };

// Type: Ground Covariances, of 3-D ground coordinates
      typedef sequence <MatrixCell, 6>  GroundCovariances;
   // Covariance matrix cells included only when correct
   //    value is known
   // Required values of “axes” string: XX, YY, ZZ
   // Optional values of “axes”  string: XY, XZ, YZ
   // Where X, Y, and Z stand for three ground coordinates

// Type: Horizontal Covariances, of 2-D ground coordinates
      typedef sequence <MatrixCell, 3> HorizontalCovariances;
   // Covariance matrix cells included only when correct
```

```
   //    value is known
   // Required values of “axes”  string for variances: XX, YY
   // Optional values of “axes”  string for covariances: XY
   // Where X and Y stand for two horizontal coordinates

// Type: Image Covariances, of image position coordinates
      typedef sequence <MatrixCell, 3>  ImageCovariances;
   // Covariance matrix cells included only when correct
   //    value is known
   // Required values of “axes”  string for variances: RR, CC
   // Optional values of “axes”  string for covariances: RC
   // Where R and C stand for Image Row and Image Column
```

4.6. Elevation Data

When a position in a monoscopic image is used to find the corresponding ground position, elevation (or height) data is usually needed. Elevation data is thus an input to several image exploitation service categories. Such elevation data could take one of several forms, including:

1. Single elevation value, to be used for one or more image positions

2. List of elevation values, to be used with a corresponding list of image positions

3. Elevation coverage, that defines the elevation as a function of ground position, to be used for one or more image positions

Each elevation could be transferred as one double precision floating point value. (Note: The SRSs used for elevations are listed as separate service inputs and outputs.) Elevation data structures defined using ISO standard IDL data types and structures are:

```
// Type: Double List, list of elevation or other numbers
      typedef sequence <double>   DoubleList;

// Type: Elevation Data Type
      enum ElevationType {
         SINGLE,  // One elevation for all image positions
         LIST,    // One elevation for each image position
         MODEL    // Elevation is modeled function of
                  // horizontal position
         };

// Type: Elevation Data, used with monoscopic image positions
      union ElevationData   switch (ElevationType) {
         case SINGLE:  double             elevation;
         case LIST:    DoubleList         elevations_list;
         case MODEL:   ElevationCoverage  elevation_model;
            // Reference to an Elevation Coverage object
         };
```

4.7. Elevation Accuracy Estimates

When elevation is used and output accuracy is needed, elevation accuracy data is a needed input to several image exploitation service categories. The accuracy of a single elevation value, or of all elevations in a list, can be specified by a one single precision floating point number. This value could have one of several meanings, including variance, standard deviation, or LE (Linear Error). A LE value could use one of several confidence probabilities. For consistency with using a covariance matrix to specify the accuracy of two or three dimensional coordinates, a variance value should be used for elevation value accuracy.

When elevation is specified by an elevation coverage, the effect of horizontal position errors on the elevation value error should be represented. This can be done using a partial 3-D covariance matrix, with a special interpretation of the values in off-diagonal cells. These off-diagonal cells can contain the ratio of the covariance value of that cell to the unknown variance of the corresponding horizontal axis. The variance cell for the elevation would have the normal meaning. The other diagonal cells in the covariance matrix, for the two horizontal coordinates, would be missing or have null values. The off-diagonal cells for the covariances between the horizontal coordinates would also be missing or have null values.

Using this approach, elevation accuracy data types can be defined. Such a set defined using ISO standard IDL data types and structures is:

```
// Type: Matrix Cell, of a covariance matrix
      struct MatrixCell {
         string <2>   axes;   // Axes of covariance matrix
         float        value;  // Units: Meters squared
         };

// Type: Elevation Covariances
      typedef sequence <MatrixCell, 3>  ElevationCovariances;
   // Covariance matrix cells included only when correct
   //    value is known
   // Required values of ìaxesî string: ZZ
   // Optional values of ìaxesî string: XZ, YZ
   // Where X, Y, and Z stand for three ground coordinates
   // Matrix cell XZ contains the ratio of XZ to XX
   // Matrix cell YZ contains the ratio of YZ to YY
```

4.8. Image SRS Definition

The SRS of an image is often specified by a ground position SRS definition plus an image geometry model, that together relate image positions to ground positions (in that ground SRS). The ground position SRS can be specified as in the draft ISO standard for geospatial metadata, including the “Spatial reference by coordinates” and lower level metadata entities (as discussed in Table 1 of Section 3.1). The image geometry model can be specified by the values of the set of parameters used by a specified mathematical model of the image geometry. These parameters are considered metadata for the image.

Image geometry model metadata is already partially discussed or implied in Abstract Specification Topic 7: The Earth Imagery Case, and in proposal document 98-033: Alternatives for Transferring Orientation Data of Digital Aerial Images. These documents describe a number of possible forms of image geometry model metadata:

1. Values of image geometry model parameters:

    1.1. For rigorous geometry models (there are many existing rigorous geometry models)

    1.2. For real-time geometry models, including:

        1.2.1. Polynomial models (Section 3.2 of Topic 7)

        1.2.2. Ratios of Polynomials (Section 3.4 of Topic 7)

        1.2.3. Universal Real-Time Model (Section 3.5 of Topic 7)

2. Positions of points in both ground and image coordinates:

    2.1. Grid of Points with Interpolation (Section 3.3 of Topic 7)

    2.2. Set of reference points, used by client for fitting parameters of image geometry model (Sections 2.3 and 3.2 of 98-033)

Technical Note: The OGC Technical Committee (TC) must answer several questions on the possible forms of image geometry model metadata, including:

1. Are there other possible forms of image geometry model metadata?

2. To what degree can or should the TC leave the selection of one or more forms of image geometry model metadata up to organizations that propose implementation specifications in response to an RFP?

3. For which future RFP should the form(s) of image geometry model metadata be selected (whether selected by the TC or by the RFP responders)?

4. Which one or more forms of image geometry model metadata should the TC select or prefer?

4.9. Features With Geometry

Features with geometry are also inputs and outputs of several image exploitation service categories. Some of these features include a full set of feature attributes, while other input/output features may include few feature attributes other than the geometry. All three OpenGIS® accepted implementation specifications for Simple Features include data formats for features with geometry, including collections of features. This document assumes that these feature formats can be used to transfer features with geometry for inputs and outputs to image exploitation services.

The possible feature geometries used as service inputs and outputs include:

1. Single point

2. Set of points

3. Grid of points

4. Linear feature geometry

5. Area feature geometry

4.10. Strategy Parameters

Some image exploitation services require inputs containing values of strategy parameters, that are used by the service algorithms to control service operations. The values of such strategy parameters are often heuristic, being experimentally found to produce the best results for some set of primary input data. However, the most effective set of values differs for different categories of other input data.

In some cases, the categories of input data affecting strategy parameters are types of ground details that are visible in the input image(s). For example, the most effective set of strategy parameter values for Elevation extraction service (Section 3.7.2.4) depends heavily on the roughness of the (visible) ground surface over the ground area to be extracted. The most effective strategy parameter values for automatic elevation extraction also depends on the amount of high-frequency detail visible in the ground cover. Similarly, the most effective set of strategy parameter values for Geodata Registration Services (Section 3.6) depends on the spatial distributions of control and tie points. (A control point has a known correct ground location, and a tie point does not).

The needed set of strategy parameters is different for different image exploitation services and is very likely to be different for different implementations of the same service. However, a name value list (as described in Section 4.14) could be used as a standard data structure for all possible sets of strategy parameters. Of course, each implementation of each service must specify the set of names and definitions that it uses for strategy parameters, together with the data type, units, and range (or domain) of the values for each parameter name. Each service probably should make all this information available to a client by providing an operation that retrieves this strategy parameter description information.

4.11. Selection of Service Operation

Selection of the specific image exploitation service desired is listed as an input for most service categories. Such selection would conventionally be done by calling a different service object or operation for each specific service. Alternately, selection can be done by using one or more

"Service Selection" inputs whose data type is an enumeration of all the alternative specific services available through one service operation. These "Service Selection" inputs could be handled like, or as an extension of, the Strategy Parameters discussed above.

4.12. Other Inputs and Outputs

Some image exploitation service inputs and outputs do not fall in the above categories. Table 4-2 lists many of these other inputs and outputs, with some information on the possible data format, mostly using ISO standard IDL data types and structures.

Service Input or Output	Possible Data Format

Computed dimensions, including:
Distance,
Area,
 	
Volume
 	
Angle
Time Difference
 	
Velocity
	`NameValueList // See Section 4.2, or use:`
	`typedef float  Distance;  // Units: meters`
	`typedef float  Area;`
	`   // Units: meters squared`
	`typedef float  Volume;`
	`   // Units: meters cubed`
	`typedef float  Angle;     // Units: degrees`
	`typedef float  TimeDifference;`
	`   // Units: seconds`
	`typedef float  Velocity;`
	`   // Units: meters per second`

Dimension accuracy estimates	`typedef float  Variance;` `   // Units: Dimension units squared`
Transformation accuracy estimates	See Position Accuracy Estimates, Section 3.5

Accuracy estimates	See Position Accuracy Estimates, Section 3.5, and:
	`typedef float  CE;         // Units: meters`
	`typedef float  LE;         // Units: meters`
	`typedef float  SphericalError;`
	`   // Units: meters`

Confidence level for CE and LE	`typedef float  Confidence;` `   // Units: probability`
Accuracy conversion parameters	`NameValueList  // See Section 3.12.1`

Measures of quality of image match	`typedef float  Confidence;`
	`   // Units: probability`
	`See Position Accuracy Estimates, Section 3.5`

Success or failure of metadata modifications	`typedef boolean  OperationSucceeded;`

Table 4-2. Possible Formats of Other Service Inputs and Outputs

Note that all quantities listed as "float" type could alternately be "double" type, if more accuracy is needed. The quantities listed as "float" type are considered unlikely to need more accuracy than provided by "float".

4.12.1. Accuracy Conversion Parameters

The "Accuracy conversion parameters" might be formatted as a Name Value List, as discussed below in Section 4.14. For conversion between covariance matrices and CE plus LE, the names and values shown in Table 4-3 might be used:

Name	Data Type	Units	Definition	Comments
Error Probability	float	(none)	Confidence probability for CE and LE error estimates	Note A
Probability Distribution Name	string	(none)	Name of probability distribution, such as "normal distribution"	
LE Multiplier	float	(none)	Multiplier of standard deviation to obtain LE with specified probability	Note B
CE Multiplier Function	sequence <float>	(none)	Multipliers of standard deviation to obtain CE with specified probability	Note C

Table 4-3. Possible Accuracy Conversion Parameters

Table Notes:

A. The possible probability values include 0.50, 0.6827, 0.90, and 0.95.

B. This multiplier is used to compute LE with the specified confidence probability from the standard deviation of the error (square root of the variance).

C. These multipliers are used to compute CE with the specified confidence probability from the standard deviation (square root of the variance) along the major axis of the error ellipse.

The CE is computed from the covariance matrix of the expected errors in two axes, either the two horizontal ground coordinates or the two image coordinates. When the error estimates in the two axes are correlated and/or are not equal, the variances are first computed for the major and minor axes of the error ellipse. The ratio of the variance in the minor axis to the variance in the major axis of the error ellipse is then computed. As this ratio varies from 0.0 to 1.0, the multiplier needed to compute CE varies from one number to a larger number.

The multipliers are specified for a variable number of evenly spaced values of the minor/major axis variance ratio, from 0.0 to 1.0. (The number of ratio values may be 21, for ratio values differing by 0.05.) For a minor/major ratio between the recorded values, linear interpolation is used.

4.13. Other Possible Outputs

For some applications, it appears desirable to make electronically available lists of the functions, operations, inputs, and outputs of a service. Such information could be provided to client software in at least two different ways:

1. A separate service could be provided that makes available information about many other services. These other services would be registered with this service-information providing service. This service would provide information on any registered service, when requested for a specified service by a client program.

2. Each service could provide one or more operations that could be called to obtain information about that service. These operations would provide information about that service. The result data listed in Section 3 for each image exploitation service category does not currently list such information, but it could be added to all service categories.

A separate service that provides information about many other services (as in item 1 above) appears to be beyond the scope of the IES SIG. We think it is beyond the IES scope since it equally supports both feature and image based OGC services. Furthermore, the OGC catalog services described in OGC Abstract Specification Topic 13 support finding such information about other services. A service that provides information about many other services may also be beyond the scope of the OGC. This may be beyond the desirable scope of the OGC since it equally supports both geospatial and non-geospatial services. For example, we think CORBA defines such a service.

Providing service operations that make information available about that service (as in item 2 listed above) might be considered within the scope of the IES SIG. However, this issue is broader than the IES SIG, since such operations should be provided by both feature and image based OGC services. Furthermore, these information-providing operations should be essentially the same for all services, and should use common software for efficiency.

In either of the two cases listed above, the data returned by an operation to get information about a service should include a list of all the operations provided by that service. For each operation, lists of the inputs and outputs (or arguments) should be returned. A list of any exceptions that can be raised by each operation should also be available. The data available about a service probably should include information expected to be used by software plus human readable information for use in error messages and by a client programmer.

The data made available for each operation's input and output might include:

1. Software Name - Software name of this quantity, perhaps fixed length and not containing spaces.

2. Human Name - Human understandable name of this quantity, variable length and can contain multiple words separated by spaces.

3. Definition - Human understandable text defining this quantity and its expected use.

4. Comments - Human understandable text providing more information about this quantity and its use

5. Quantity Required - Specifies whether a value is required or optional for this quantity.

6. Data Type - Specifies the data type of this quantity, perhaps selecting from a separately specified set of data types.

7. Units Name - Specifies the physical units of values for this quantity, using human readable text. Omitted when not applicable.

8. Minimum Value - Specifies the maximum value of a numerical quantity. Omitted when not applicable.

9. Maximum Value - Specifies the maximum value of a numerical quantity. Omitted when not applicable.

10. Default Value - Specifies the default or null value for this quantity. Omitted when not applicable.

11. Legal Value Expected - Specifies if the value is expected to be one of an enumerated set of standard or legal values.

12. Legal Value and Meaning - Specifies a legal value of this quantity, and the human readable meaning of that value. This data is repeated for each legal value, and is omitted when not applicable.

The data available for each exception that can be raised by operations might include:

1. Software Name - Software name of this exception, perhaps fixed length and not containing spaces.

2. Human Name - Human understandable name of this exception, variable length and can contain multiple words separated by spaces.

3. Definition - Human understandable text defining this exception and the conditions when it is raised.

4. Comments - Human understandable text providing more information about this exception and its use, including recovery suggestions.

Additional data available for each operation might include:

1. Software Name - Software name of this operation, perhaps fixed length and not containing spaces.

2. Human Name - Human understandable name of this operation, variable length and can contain multiple words separated by spaces.

3. Function - Human understandable text defining the function(s) performed by this operation and its expected use.

4. Comments - Human understandable text providing more information about this operation and its use.

4.14. Hierarchical Name Value Lists

A Name Value List is a well-known data structure for flexibly transferring data. A Name Value List stores a variable length list of name and value pairs. Each Name is recorded as a character string. Different names can have associated values of different data types, including integer number, floating point number, and character string. The data type used for each value is selected appropriate to the definition of the associated name.

A hierarchy of Name Value Lists can be used. That is, the value of a Name Value pair can be allowed to be a lower level Name Value List. Such a Name Value pair can also be allowed to be repeated, using the same Name but containing different Values in different lower level Name Value Lists. When hierarchical Name Value Lists are used, the top level Name Value List will often contain one or more values that are lower level Name Value Lists.

Using ISO standard IDL, the structure of hierarchical Name Value Lists is:

```
// Type: Name
      typedef string     Name;

// Type: Name Value
      struct NameValue {
         Name   name;    // Computer name of item
         any    value;   // Value of item
         };
   // Note: The ìanyî type includes a Name Value List and
   //    probably other data structures

// Type: Name Value List
      typedef sequence <NameValue>   NameValueList;
```

The value in a Name Value pair can also be allowed to be a data structure other than a Name Value List. Some other useful data structures include:

1. Position coordinates, a structure containing the values of two or three coordinates

2. List (or sequence) of simple values, such as a list of character string values used for a list of names

3. List (or sequence) of simple data structures, such as position coordinates data structures used for the vertices of a polygon

A metadata entity, section, or set could be implemented or transferred using a hierarchical Name Value List data structure. Similarly, a Name Value List structure could be used for a metadata set, a feature, a feature collection, a set of strategy parameters, or many other service inputs and outputs.

If and when a Name Value List is used to transfer service inputs and outputs, the specific set of Names and Values used must still be carefully specified. If service inputs and outputs are specified in ISO standard IDL using Name Value Lists as defined above, then the specific set of Names and Values used must be separately specified (not in the interface IDL). A set of Names and Values could be specified in a variety of ways, including using tables such as Table 4-3 in Section 4.12.1 or the tables used in the draft ISO Metadata Standard, 15046-15.

4.15. Input and Output Specifications

Whether or not Name Value Lists are used, all service inputs and outputs must be completely specified, to permit client software to be written to correctly use that service. Furthermore, the service input and output specifications should be readily available and clearly understandable to the applications programmer. In the past, data inputs and outputs have rarely been completely and clearly specified in a readily available and easily found location.

One possible way to make input and output specifications available is for a service to provide an operation by which a client can get requested data specifications. For client software, the requested data specifications might be returned in the form of a hierarchical Name Value List.

For an item in a Name Value List, the information needed to completely specify an input or output quantity generally includes:

1. Software Name - Software name of this quantity, perhaps fixed length and not containing spaces. Used as the "Name" in name value lists.

2. Human Name - Human understandable name of this quantity, variable length and can contain multiple words separated by spaces.

3. Parent Name - Name of parent Name Value List that includes this Name Value, if any. Can be omitted when not applicable.

4. Definition - Human understandable text defining this quantity and its expected use.

5. Comments - Human understandable text providing more information about this quantity and its use

6. Quantity Required - Specifies whether a value is required or optional for this quantity.

7. Maximum Repetitions - Specifies the maximum number of times this name value pair can be repeated.

8. Data Type - Specifies the data type of this quantity, usually selecting from a separately specified set of data types.

9. Units Name - Specifies the physical units of values for this quantity, using human readable text. Omitted when not applicable.

10. Minimum Value - Specifies the maximum value of a numerical quantity. Omitted when not applicable.

11. Maximum Value - Specifies the maximum value of a numerical quantity. Omitted when not applicable.

12. Default Value - Specifies the default or null value for this quantity. Omitted when not applicable.

13. Legal Value Expected - Specifies if the value is expected to be one of an enumerated set of standard or legal values.

14. Legal Value and Meaning - Specifies a legal value of this quantity, and the meaning of that value. This data is repeated for each legal value, and is omitted when not applicable.

4.15.1. Name Value List Use Objects

A Name Value List could be implemented by an object of a general “Name Value List Use” (concrete) class. That is, a Name Value List Use object might be passed as a service input or output, instead of passing a data structure. (An object can be an operation input or output in CORBA, but perhaps not in other Distributed Computing Platforms.)

In addition to storing a Name Value List as its internal state, the Name Value List Use class of objects can provide operations to conveniently access the data stored. For example, the Name Value List Use class might provide the operations listed in Table 4-4.

Operation Name	**Function**	**Inputs**	**Outputs**
Create Object	Create new object, initially empty	–	new name value list use object
Copy Object	Create new object by copying existing name value list use object	old name value list use object	new name value list use object
Append Name Value	Add new name and value record to end of state name value list	name, value	–
Get First Name Value	Retrieve first name and value record from state name value list	–	name, value
Get Next Name Value	Retrieve next name and value record in state name value list, after last record retrieved by Get Next Name Value or by Get First Name Value	–	name, value
Get Selected Name Value	Retrieve value for specified record in state name value list	name, partial value name value list use object	current value
Set Selected Name Value	Change value of specified record in state name value list	name, partial value name value list use object	–
Remove Name Value	Remove selected record from state name value list	name, partial value name value list use object	–
Delete Object	Delete this object	–	–

Table 4-4. Possible Operations of Name Value List Use Class

4.16. ISO Standard IDL

Many of the ISO (and CORBA) standard Interface Definition Language (IDL) data types and structures are summarized in Table 4-5. Most of these data types are common to the C++ programming language.

IDL Name	Meaning
short	16 bit signed integer
long	32 bit signed integer
unsigned short	16 bit unsigned integer
unsigned long	32 bit unsigned integer
float	32 bit floating point number
double	64 bit floating point number
char	one 8 bit text character
string	sequence of 8 bit text characters, usually of unlimited length
boolean	one bit data type
enum	enumeration of all possible values
union	discriminated union, containing different data types depending on a specified enum data type
sequence	ordered list of data items or data structures, usually of unlimited length
struct	structure or record, containing specified list of data items, sequences, or lower level structures
any	any data type, including any object identifier or any user defined data type (e.g., a name value list)

Table 4-5. ISO IDL Data Types and Structures

Table 4-6 lists some other IDL terms with the terms used elsewhere for the same concepts.

IDL Term	Other Terms for Same Thing
interface	class, object type
operation	method, function, subroutine
attribute	member, visible data
parameter	argument, input, output
readonly	attribute value can be read but not changed
in	input argument or parameter
out	output argument or parameter
raises	defines which special exceptions can be raised by operation when normal execution is not possible
const	constant data value
typedef	custom type definition
//	comment delimiter, start of comment at end of line

Table 4-6. Other ISO IDL Terms

5. Future Work

5.1. Software Frameworks

The interfaces to each image exploitation service or category could be defined independently. If defined independently, the interfaces to each service or category would tend to use different formats and contents for the same or similar data, used as inputs and/or outputs of different services. However, it would be better if multiple service categories use interfaces that are defined to use the same data formats and contents for the same or similar data, used as inputs and/or outputs of different services.

Such use of the same interface formats and contents by multiple service categories means developing what is often called a software framework. A software framework defines standardized interface aspects across multiple software components, where these components often provide different user services. Use of a software framework facilitates using multiple complementary services together, including using different services in mix-and-match fashion.

A key issue is: How can the Open GIS Consortium (OGC) obtain multiple implementation specifications that fit into one or more software frameworks, to the maximum useful extent? More detailed questions include:

1. Should the OGC request that vendors propose a software framework, or just trust that vendors will propose a framework when appropriate?

2. If the OGC requests that vendors propose a software framework, should this request be in a separate RFP, or in an RFP that also requests implementation specifications for interfaces to specific services?

3. If the OGC requests a software framework in an RFP for specific service interfaces, in which specific RFPs should a software framework be requested?

4. How should selected image exploitation services be combined into one RFP (or separated into different RFPs) to improve the probability and quality of proposed software frameworks?

Note that the taxonomy of image exploitation services groups these services into categories with similar interfaces. We hope that such a grouping of services will improve the probability and quality of proposed software frameworks. For example, item 3 in Section 1 (Image Modification Services) includes many lower level services (because they need somewhat similar interfaces). Specifically, these Image Modification Services include many Change pixel values services (item 3.1), many Change pixel positions services (item 3.2), and many other services (items 3.3 and 3.4).

Similarly, item 1 in Section 1 (Ground Coordinate Transformation Services) includes many services that should have largely identical interfaces. Also, Section 2 (Image Coordinate Transformation Services) includes many services that should have largely identical interfaces. Furthermore, both ground and image coordinate transformation services should have largely identical interfaces.

6. Appendix A. Acronyms and Glossary

6.1. Acronyms

AOI	Area Of Interest
CE	Circular Error
DRA	Dynamic Range Adjustment
IDL	Interface Definition Language
ISO	International Standards Organization
LE	Linear Error
OGC	Open GIS Consortium
RFP	Request for Proposals
RRDS	Reduced Resolution Data Set
SRS	Spatial Reference System
TTC	Tonal Transfer Curve
USIGS	United States Imagery and Geospatial System

6.2. Definitions

Editor's Note: Most of these definitions are copied from the USIGS Glossary. That glossary includes definitions extracted from many other documents, including ISO and OGC documents. The definitions not copied are annotated "(Note: This definition is not in the USIGS Glossary.)".

Absolute accuracy

Absolute accuracy is defined as the statistic which gives the uncertainty of a point with respect to the datum required by a product specification. This definition implies that the effects of all error sources, both random and systematic, must be considered.

Accuracy

The degree to which information on a map or in a digital database matches true or accepted values. Accuracy pertains to the quality of data and the number of errors contained in a dataset or map. In discussing a GIS database, it is possible to consider horizontal and vertical accuracy with respect to geographic position, as well as attribute, conceptual, and logical accuracy. The effect of inaccuracy and error on a GIS solution is the subject of sensitivity analysis. Accuracy, or error, is distinguished from precision , which concerns the level of measurement or detail of data in a database.

Attribute

1. A named property of an object. An attribute belongs to a certain attribute type and has a value taken from the domain belonging to the attribute type.

2. A characteristic of a site or phenomenon. May be physical, social, economic or titular in nature. For example, road types and road names are road attributes.

3. Recorded property of a digital feature. An attribute belongs to a certain attribute type and has a value taken from the domain belonging to the attribute type. For example, road types and road names are road attributes.
(Note: This definition is not in the USIGS Glossary.)

Attribute Data

Descriptive information about features or elements of a database. For a database feature like census tract, attributes might include many demographic facts including total population, average income, and age. In statistical parlance, an attribute is a "variable," whereas the database feature represents an "observation" of the variable.

Catalog

A collection of entries, each of which describes and points to a feature collection. Catalogs include indexed listings of feature collections, their contents, their coverages, and other metadata. Registers the existence, location, and description of feature collections held by an Information Community. Catalogs provide the capability to add and delete entries. At a minimum Catalog will include the name for the feature collection and the locational handle that specifies where this data may be found. The means by which an Information Community advertises its holdings to members of the Information Community and to the rest of the world. Each catalog is unique to its Information

Community.
(Note: This definition is not in the USIGS Glossary.)

Circular Error

An accuracy figure representing the stated percentage of probability that any point expressed as a function of two linear components (e.g., horizontal position) will be within the given figure. Commonly used are Circular Error Probable (CEP [50 percent]), and CE (90 percent). A horizontal measurement on the ground, in feet or meters, defining a radius of a circle, within which an object of known coordinates should be found on an image. The CE value should have some measure of probability (P) associated with it. For example, a CE of 100 meters and .9 P, means that 90 percent of the time the object will fall within a circle having a radius of 100 meters.

Classification

The assignment of a discrete value to each position in an image or other data. Image classification usually uses multiple bands of a multispectral image, or uses multiple images which have been accurately registered to one another. Classification can use the values at a single pixel, or can use multiple pixel values in a small region centered on the pixel being classified. Classification can assign an independent value to each pixel, but often assigns the same value to multiple adjacent pixels. For example, isolated pixels with a different initial classifications may be reassigned the classification of the adjacent pixel(s) with similar pixel values. A wide variety of methods can be used for classification, including Tomlin's "Map Algebra", fuzzy logic, and neural nets.
(Note: This definition is not in the USIGS Glossary.)

Compilation

1. (JCS) Selection, assembly, and graphic presentation of all relevant information required for the preparation of a map or chart. Such information may be derived from other maps or charts or from other sources.

2. (photogrammetry) The production of a new or recompiled map, chart, or related product from aerial photographs and geodetic control data by use of photogrammetric instruments. Also called **photogrammetric compilation; stereocompilation.** See also **recompilation.**

Concatenated transformation

Sequential application of multiple transformations.
(Note: This definition is not in the USIGS Glossary.)

Coordinate Conversion

An exact transformation of position coordinates from one Spatial Reference System (SRS) to another. This term is used only when the SRS transformation is known exactly.
(Note: This definition is not in the USIGS Glossary.)

Coordinate Transformation

An approximate transformation of position coordinates from one Spatial Reference System (SRS) to another. For example, this term is used when the transformation coefficients are determined by least squares adjustment. This term is strictly used only when the SRS transformation is known only approximately. This term is loosely used when the SRS transformation is known either approximately or exactly.
(Note: This definition is not in the USIGS Glossary.)

Covariance matrix

A detailed form of position accuracy data, sometimes called a variance-covariance matrix. For three ground coordinates, a covariance matrix is a 3 by 3 matrix, with the matrix rows and columns each corresponding to the three coordinates. For just two horizontal ground coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two horizontal coordinates. Similarly, for two image coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two image coordinates.

The covariance matrix cells contain the expected average values of the product of the error in the matrix row coordinate times the simultaneous error in the matrix column coordinate. For absolute accuracy, the diagonal matrix cells contain the error variances of the corresponding ground coordinates, or the squares of the standard deviations. The off-diagonal cells contain the covariances between the errors in the corresponding ground coordinates; these covariances will be zero when the errors in different coordinates are not statistically correlated. All covariance matrices are symmetrical, meaning that the same cell values appear on both sides of the diagonal cells.

Covariance matrices can be used to record absolute and/or relative accuracies. A covariance matrix for relative accuracy uses the three (or two) coordinates of one point for matrix rows and the three (or two) coordinates of the second point for matrix columns. A complete covariance matrix for N specific points would contain 3N rows by 3N columns.
(Note: This definition is not in the USIGS Glossary.)

Coverage

1. GIS coverages (including the special case of Earth images) are two- (and sometimes higher-) dimensional metaphors for phenomena found on or near a portion of the Earth's surface. Fundamentally, coverages (and images) provide humans with an n-dimensional (where n is usually 2, and occasionally 3 or higher) "view" of some (usually more complex) space of geographic features. The power of coverages is their ability to model and make visible spatial relationships between, and the spatial distribution of, Earth phenomena.

2. A coverage is a special case of (or a subtype of) feature.

Delineate

Two dimensional collection of feature position in an image.
(Note: This definition is not in the USIGS Glossary.)

Dimension

Exploitation

The evaluation of an image or multiple images to extract the information contained within the image(s) as it pertains to a specific list of questions or general categories of questions. Exploitation may result in the creation of a report or product to disseminate the information, whether it be to a requester or to a data base.

Extraction

Two or three dimensional collection of information from one or more images. In monoscopic extraction, extraction of each point is normally from one image. In stereoscopic extraction, extraction of each point is normally from one stereoscopic pair of images (or stereomates), sometimes called "conjugate feature extraction". In the case of range images, such as SAR or laser images, a one dimensional extraction of distance might be done, to determine the distance from the camera to a feature.
(Note: This definition is not in the USIGS Glossary.)

Feature

A digital representation of a real world entity or an abstraction of the real world. It has a spatial domain, a temporal domain, or a spatial/temporal domain as one of its attributes. Examples of features include almost anything that can be placed in time and space, including desks, buildings, cities, trees, forest stands, ecosystems, delivery vehicles, snow removal routes, oil wells, oil pipelines, oil spills, and so on. Features are usually managed in groups as feature collection.

Feature attribute

An essential trait, quality, or characteristic of a geographic feature.

Feature collection

A set of related features managed as a group.

Feature type

Class of features with common characteristics

Framework

In terms of software design, a reusable software template, or skeleton, from which key enabling and supporting services can be selected, configured and integrated with application code.
(Note: This definition is not in the USIGS Glossary.)

Image

The permanent record of the likeness of any natural or man-made features, objects, and activities reproduced on photographic materials. This image can be acquired through the sensing of visual or any other segment of the electromagnetic spectrum by sensors, such as thermal infrared, and high resolution radar.

Image column

Position of an image pixel in the horizontal direction, as that image is normally viewed. Sometimes referred to as (image) sample.

Image compression

An operation that, through various techniques, reduces the quantity of stored data needed to represent a digital image.

Image correlation

The matching of position and physical characteristics between images of the same geographic area from different types of sensors, between sensor images and a data base, or between two images from the same sensor.

Image data

All data collected by a sensor, which after processing, comprises an image.

Image enhancement

Any one of a group of operations that improve the detectability of features in an image. These operations include contrast improvement, edge enhancement, spatial filtering, noise suppression, image smoothing, and image sharpening.

Image row

Position of an image pixel in the vertical direction, as that image is normally viewed. Sometimes referred to as (image) line.

Image perspective transformation

This product type includes video and hardcopy format showing several views of a scene with other than the original image geometry. This product type is used to simulate movement around a scene at ground or flight level.

Interface

A shared boundary between two functional entities. A standard specifies the services in terms of the functional characteristics and behavior observed at the interface. The standard is a contract in the sense that it documents a mutual obligation between the service user and provider and assures stable definition of that obligation.

Linear Error

1. A one-dimensional error (such as an error in elevation) defined by the normal distribution function.

2. Vertical error at the target. The accuracy with which the elevation of the target can be determined. The LE at a point is a value such that the true elevation of the point can be expected to have the given value plus or minus LE with same degree of probability (usually 0.9 P).

3. In a Linear Error, we record that the value has a specified probability of having an error magnitude less than a specified distance.
(Note: This definition is not in the USIGS Glossary.)

Mensuration

1. The act, process, or art of measuring.

2. That branch of mathematics dealing with the determination of length, area, or volume.

Metadata

Data about the content, quality, condition, and other characteristics of data.

Monoscopic image

A single image taken of the target.

Mosaic

1. An assembly of overlapping aerial photographs which have been matched to form a continuous photographic representation of a portion of the Earth's surface. Also called aerial mosaic.

2. An assembly of two or more overlapping or adjacent orthorectified (or rectified) images to form a continuous image of a larger ground area. The images mosaicked are normally first radiometrically matched to minimize visible discontinuities in the mosaic between the adjacent

images. Unrectified images are not normally mosaicked, because the effects of camera tilt and terrain relief will leave large position discontinuities along the mosaicking lines between different original images.
(Note: This definition is not in the USIGS Glossary.)

Orthorectification

1. The process of removing image displacement caused by tilt and terrain relief. Tilt, however, is not relevant in radar images.

2. The process of transforming one input image into an output image possessing a perpendicular parallel projection. Orthorectified images thus have a constant scale. The orthorectification process removes image tilt and displacement due to terrain elevation. Orthorectification requires using digital elevation data, usually in grid form. Orthorectification is sometimes termed "differential rectification" since the input image is separately rectified to cover each elevation grid cell.
(Note: This definition is not in the USIGS Glossary.)

Orthophotograph

1. A photographic copy, prepared from a perspective photograph, in which the displacements of images due to tilt and relief have been removed.

2. An image produced by **orthorectification**.
(Note: This definition is not in the USIGS Glossary.)

Orthophoto stereomate

An image generated to support stereoscopic viewing with a specific orthophotograph. An orthophoto stereomate can be produced by methods similar to those used in producing the orthophotograph, except that image details are deliberately displaced by an amount simulating displacement due to the relief that was removed from the orthophoto.
(Note: This definition is not in the USIGS Glossary.)

Perspective scene generation

See **Image Perspective Transformation**

Pixel

1. 2-dimensional picture element that is the smallest nondivisible element of a digital image.

2. In image processing, the smallest element of a digital image that can be assigned a gray level.
Note: This term originated as a contraction for "picture element".

Photogrammetry

1. Use of aerial photographs to produce planimetric and topographic maps of the earth's surface and of features of the built environment. Effective photogrammetry makes use of ground control by which aerial photographs are carefully compared and registered to the locations and characteristics of features identified in ground-level surveys.

2. The science of mensuration and geometric adjustment of, an aerial photograph or satellite image. Photogrammetry requires: a mathematical model of the image formation process, computation of the internal geometry of an image, and subsequent correction of imagery based upon the ground relationship for every part of the image. Correction of imagery based on computational algorithms and measurement of geometrical position in an image.

Product

A completely specified data set, comprised of a set of profiles; specifically including , the schema, metadata, quality information, reference system, structure primitives, and encoding.

Rectification

1. In photogrammetry, the process of projecting a tilted or oblique photograph onto a horizontal reference plane. [Although the process is applied principally to aerial photographs, it may also be applied to the correction of map deformation.]

2. The geometric adjustment of image pixels to remove distortions caused by the imaging sensor and the geometry of the sensor to the ground. For the removal of terrain relief displacement see orthorectification.

3. The process of projecting a tilted or oblique image onto a selected plane or other surface. The plane is often horizontal, but can be tilted to achieve some desired condition, such as to better fit the local surface of the earth. Rectification of an ideal frame image is a plane-to-plane projection. Rectification of non-ideal images and of images with non-planar geometries (such as pushbroom images) includes corrections for the known image deviations from a plane, using an accurate mathematical model of the image geometry.
(Note: This definition is not in the USIGS Glossary.)

Reduced Resolution Data Set (RRDS)

Original, high-resolution imagery is useful for many applications (especially close-up displays), but for overall displays there may be too much data to process. For example, if the raw image consists of 16K X 16K pixels, it is impossible to fit this much data into the cathode ray tube refresh memory at once to build an overview display. Therefore, RRDSs are created (as a preprocessing step) and are used as input by overview displays whenever the original high-resolution data are impossible to use. An original 16K X 16K (=256 megabytes) may be reduced to 1K X 1K (=1 megabyte) for overview purposes.

Relative accuracy An accuracy evaluation based on random errors in determining the positional accuracy of one point feature with respect to another feature.

Request for Information (RFI)

A general request to the industry to submit information to one of the Task Force Working Groups in anticipation of an RFP or to fill a gap in the Abstract Specification.
(Note: This definition is not in the USIGS Glossary.)

Request for Proposals (RFP)

An explicit OGC request to the industry to submit proposals to one of the Task Force Working Groups for technology satisfying a portion of the Abstract Specification. RFPs result in Implementation Specifications.

Spatial Reference System (SRS)

Description of how geographic objects are positioned in space.

Spherical Error

A spherical error records that a 3-D position has a specified probability of having a vector error magnitude less than a specified distance.

Stereoscopic images

1. Two images taken of a single target on one imaging pass to allow three-dimensional viewing of a target.

2. Two photographs [or images] with sufficient overlap of detail to make possible stereoscopic examination of an object or an area common to both.

3. Two or more images of the same object taken from different imaging positions, and thus different object viewing directions, that can be used to determine object position in three-dimensions. Two stereoscopic images are often taken from different points along one flight path, but there are also stereoscopic images from different flight paths.
(Note: This definition is not in the USIGS Glossary.)

Tile

1. Partition of a dataset based on the definition of a geographic area.

2. Part of an image based on rectangular or square image areas.
(Note: This definition is not in the USIGS Glossary.)

Tiling scheme

The scheme used to define tile shape and size, and unique tile identification number.

Transformation

1. (photogrammetry) The process of projecting a photograph (mathematically, graphically, or photographically) from its plane onto another plane by translation, rotation, and/or scale change. The projection is made onto a plane determined by the angular relations of the camera axes and not necessarily onto a horizontal plane. See also rectification.

2. (surveying) The computational process of converting a position from UTM or other grid coordinates to geodetic, and vice versa; from one datum and ellipsoid to another using datum shift constants and ellipsoid parameters. The survey position of a point is frequently given in several different grids or ellipsoids; local datum and Doppler-derived WGS 84 are common requirements.

Triangulated Irregular Network (TIN)

Triangulated Irregular Network (TIN) A terrain model created from continuously connected triangles derived from the Delauney algorithm. The vertices of the triangles form irregularly spaced elevation posts. Unlike a grid, the TIN allows extra information to be displayed in areas of complex relief without displaying dense or redundant data gathered in areas of simple relief.

Alternately, the TIN triangles can be derived using other constraints, such as Thiessen triangulation.

(Note: This discussion is not in the USIGS Glossary.)

7. Appendix B. The Geospatial Data Extraction Process

The functional block diagram in Figure 7-1 shows how geospatial data can be extracted from images. In this diagram, each box represents a function or activity that can be performed when needed, and each arrow represents a flow of data between functions. (Note: This diagram was adapted from one used in the previous Earth Imaging Working Group, which was adapted from a diagram in the response to RFI #2 submitted to the OGC by the TRIFID Corporation.)

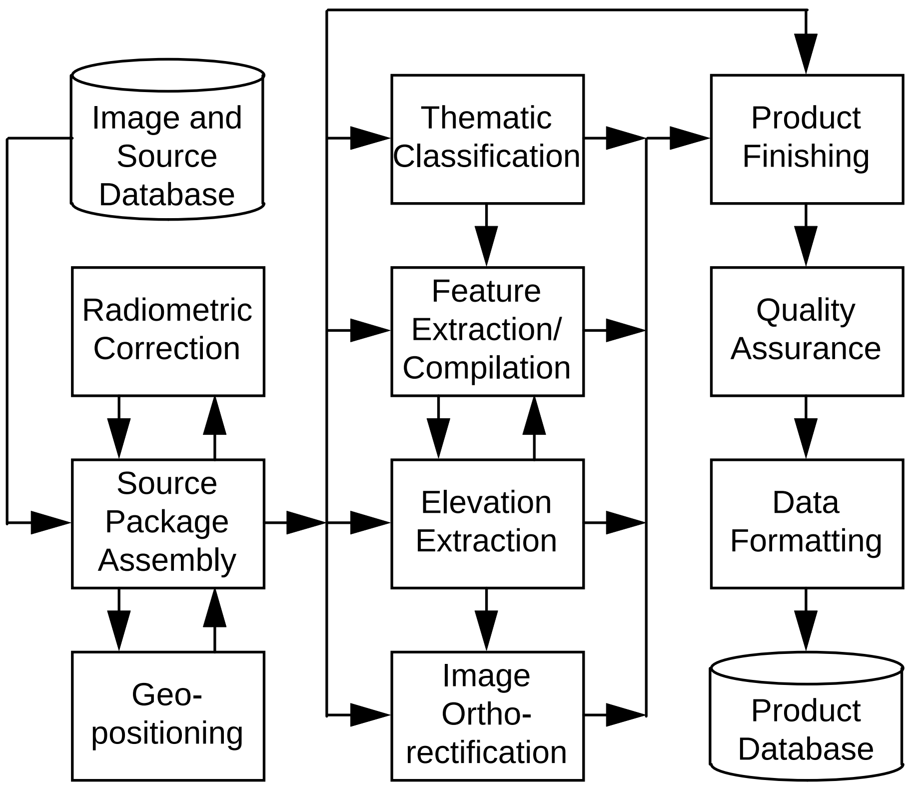

Figure 7-1. Image Exploitation Block Diagram

Table 7-1 summarizes the function of each box shown in the above diagram, plus some of its inputs and outputs. (Note: Some of this information was adapted from the response to RFI #2 submitted to the OGC by the TRIFID Corporation.) The inputs to many boxes are listed as “Reformatted Images”, and this is thus an output of the “Source Package Assembly” box. The term “Reformatted Images” is used since image reformatting is often required, from the formats stored in the ”Image and Source Database” to the formats required by the software used by other functional boxes. This reformatting can include image data decompression and also reformatting of the Image Metadata. This Image Metadata either directly or indirectly defines pairs of images suitable for stereoscopic elevation and feature extraction.

Name	Function	Inputs	Outputs
Source Package Assembly	Select, obtain, and quality check source materials needed for project, and format data for exploitation processes to be used	Images, Image Metadata, Control Points, Ancillary Data	(see inputs to other functions)
Radiometric Correction	Correct and/or enhance image radiometry (colors and gray levels)	Reformatted Images, Image Radiometric Calibration Metadata	Radiometrically Corrected Images, Image Radiometric Correction Metadata
Geopositioning	Adjust image geometry metadata to register images to each other and/or to control points	Reformatted Images, Image Geometry Metadata, Control Points	Adjusted Image Geometry Metadata, Image Accuracy Metadata
Thematic Classification	Classify land use or land cover, using single or multiple multispectral images plus other data (such as existing digital feature data)	(Radiometrically Corrected) Images, Orthorectified Images, Ancillary Data (ground truth data)	Classified Images, Classified Image Metadata
Feature Extraction/ Compilation	Extract digital feature data from stereoscopic or monoscopic images, or from orthorectified images and image mosaics	Reformatted Images, Orthorectified Images, Classified Images, Image Mosaics, Adjusted Image Geometry Metadata, Elevation Data, Ancillary Data (existing feature data)	Feature Data, Feature Metadata, Geomorphic Features
Elevation Extraction	Extract and edit digital elevation data (grid, TIN, and/or contours) from stereoscopic images	Reformatted Images, Adjusted Image Geometry Metadata, Geomorphic Features, Ancillary Data (existing elevation data)	Elevation Data, Elevation Metadata
Image Ortho-rectification	Orthorectify or rectify to selected horizontal coordinate datum and projection. Optionally mosaic multiple images after radiometric and geometric matching.	Radiometrically Corrected Images, Adjusted Image Geometry Metadata, Elevation Data	Orthorectified Images, Rectified Images, Image Mosaics
Product Finishing	Prepare complete product, combining multiple data types as needed, and assemble product metadata	Feature Data, Elevation Data, Orthorectified Images, Image Mosaics, Classified Images, Radiometrically Corrected Images	Complete Products, Product Metadata
Quality Assurance	Review complete product and metadata for completeness, accuracy, and quality, and update product metadata	Complete Products, Product Metadata	Complete Products, Checked Product Metadata
Data Formatting	Convert complete product and metadata into correct format for output and storage	Complete Products, Checked Product Metadata	Formatted Products, Formatted Product Metadata

Table 7-1. Process Box Functions, Input and Outputs

A wide variety of use cases are implied by the diagram in Figure 7-1, including all the use cases defined in Section **Error! Reference source not found.**. Each step listed in Section **Error! Reference source not found.** is part (or all) of a process box shown in Figure 7-1. For example, the steps listed for the “Produce Feature Product” use case in Section 2.1.2.1 correspond to the process box functions shown in Figure 7-1 as listed in Table 7-2.

Use Case Step	Image Exploitation Process
1) Prepare feature source package	Source Package Assembly,

	Geopositioning
2) Edit elevation data	Elevation Extraction
3) Display features overlaid on images	Feature Extraction/Compilation
4) Edit existing feature	Feature Extraction/Compilation
5) Extract feature from image	Feature Extraction/Compilation
6) Check new product	Quality Assurance
7) Release new feature product	Data Formatting

Table 7-2 . Image Exploitation Processes Used to Produce Featrure Product

Although many more use cases could be derived from Figure 7-1 and Table 7-1, such use cases have not yet been explicitly defined. Although not presented in use case format, Figure 7-1 and Table 7-1 imply a number of image exploitation services, and so are documented here.

8. Appendix C. OGC Image Levels

The OGC has defined a set of image levels to be used in labeling processed images. These image levels imply some additional use cases that would use image exploitation services, but are not documented here. The OGC list of image levels is:

- A **Level 0** image includes systems corrections only. Its metadata is the raw information extracted from telemetry.
- A **Level 1** image admits refinement and additions to metadata. It also allows radiometric and geometric calibrations using external information.
  - A **Level 1A** image supports geographic formatting using the sensor system's geographic knowledge. The image pixel values are not adjusted, but based on internal system information, metadata values may change, or new metadata is added.
  - A **Level 1R** image provides radiometric adjustment using the sensor system's radiometric calibration data measurements.
  - A **Level 1G** image has photogrammetric geopositioning of the sensor data using external geo-referenced information.
  - A **Level 1N** image is a non-mapping product.
- A **Level 2** image involves image pixel modification, and possibly the compilation of products from Level 1 data.
  - A **Level 2R** image possesses radiometric modification of level 1 data using external information. An example is atmospheric correction.
  - A **Level 2G** image has been geometrically transformed (resampled) using photogrammetric geopositioning. Examples include rectification and orthorectification.
  - A **Level 2T** product consists of terrain information compiled from level 1G images.
  - A **Level 2F** product consists of feature or thematic classification from level 1G images.
- A **Level 3** product involves the extraction or classification of information from level 2 products.
  - A **Level 3F** product consists of features or thematic information extracted from level 2 products
  - A **Level 3T** product consists of terrain information extracted from level 2 products
- A **Level 4** products consists of symbolized information extracted from level 2 or 3 products.
  - **Level 4F** and **4T** products support feature symbolization and terrain symbolization respectively.