Interoperability in GIS
Interoperability and GIS

- Geospatial data is everywhere!
  - GIS evolving beyond isolated communities
  - GIS merging with broader IT infrastructures
  - Distributed networks and Web Services

- One requires interoperability standards

Interoperability = ability of diverse systems and organizations to inter-operate together.
From GIS to Spatial Data Infrastructures (SDIs)

- A framework of spatial data, metadata, services, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way.

- The technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data.

- The relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data and services. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers.
Implications

- Data and metadata should not be managed centrally (as done in GIS) but by the data originator and/or owner; tools and services connect via computer networks to the various sources.

- NOTE: good coordination between all the actors is necessary and the definition of **standards** is very important.

- Due to its nature (size, cost, number of interactors) an SDI is usually government-related.
For example…

- Infrastructure for Spatial Information in the European Community (INSPIRE)
- *Sistema Nacional de Informação Geográfica (SNIG)*  
  - [http://snig.igeo.pt](http://snig.igeo.pt)
- Canadian Geospatial Data Infrastructure (CGDI)
- Australian Spatial Data Infrastructure (ASDI)  
  - State-level SDI’s in development: Queensland, W. Australia, …
- U.S. National Spatial Data Infrastructure (NSDI)
An SDI typically includes thematic “base map” data with broad interest across agencies and other users (insurance, utilities, etc.)

- **Cadastre**: property parcels
- **Transportation**: roads, rail, bridges, tunnels, trails, bus routes
- **Boundaries**: cities, parks, military facilities
- **Points of Interest**: hospitals, malls, churches, airports, bus stations, stadiums, auditoriums, other meeting places
- **Water resources**: springs, wells, rivers, lakes
- **Utilities**: power plants, power lines, gas lines, water treatment facilities, water lines

…these vary somewhat across different SDI’s
What makes SDI’s special?

Not just a simple extension of I.T. cyberinfrastructure

- **Spatial data payloads** require application-specific metadata, clients, web services, even XML tools.

- **Quantities of data** coming from satellite and other earth observation sensors are in terabytes/day – for now

- **Downloading and rendering** a computer-screen-sized JPEG of a map is much simpler and faster (in general) than downloading the potentially hundreds of thousands of vectors & millions of vertices comprising the corresponding map content… but both forms of data are needed.

- **Institutional barriers** can play a significant role in SDI effectiveness
What makes it work?

- **Standards** for exchanging geospatial & temporal data have been in development since early 1990s through work of the Open Geospatial Consortium (OGC) and ISO TC211.
  - Web services since 2000

  - **ISO TC211 standards form the foundation**, for example:
    - 19103 Conceptual Schema
    - 19107 Spatial Schema
    - 19108 Temporal Schema
    - 19111 Coordinate Reference
    - 19115 Metadata
    - 19123 Coverage Schema

- **OGC specifications implement the standards**, for example:
  - Web Mapping Service (WMS): *simple graphic images*
  - Web Feature Service (WFS): *vector data*
  - Web Coverage Service (WCS): *gridded data (rasters)*
  - Catalog Service: *portal index*
  - Geography Markup Language (GML): *XML Schemas and datasets*
Enabling a Geospatial Information Architecture

Building on http, XML and Web services, the spatial web is currently enabled by OGC standards, such as…

- Feature Model & GML (OGC & ISO)
- Web Map Service (OGC & ISO)
- Style Layer Descriptor (OGC)
- Web Feature Service (OGC)
- Filter Specification (OGC)
- Web Terrain Service (OGC)
- Web Coverage Service (OGC)
- Catalog (OGC)
- Metadata (ISO 19115 & OGC)

Geospatial information (e.g., vector, raster, and metadata) can be managed through OGC web services in a Web Centric context.
## Standards Referenced by Various SDI’s

<table>
<thead>
<tr>
<th>Standard Name</th>
<th>Canada CGDI</th>
<th>US NSDI</th>
<th>GDI NRW</th>
<th>Catalonia Spain</th>
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<td>FGDC Content Standard for Digital Geospatial Metadata</td>
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<td>OGC Web Coverage Service</td>
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<tr>
<td>OGC Catalogue Services 2.0 HTTP Protocol Binding (CS-W)</td>
<td>✔</td>
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</tbody>
</table>
With OGC web services, an analyst or operator can dynamically access that data which is relevant to the task at hand, directly from the authoritative data steward, using a variety of tools.
Web Map Service(s) (WMS) can produce multiple maps

One or multiple **GetMap** request:
Catalogs leverage ISO conformant metadata

Support publishing and discovery of distributed geospatial data and associated services

- OGC Catalog Service 2.0,
- ISO 19119 Metadata Standard
Coming Fast: Sensor Webs

- Sensors connected to and discoverable on the Web
- Sensors have position & generate observations
- Sensor descriptions available
- Services to task and access sensors
- Local, regional, national scalability
Web Services and Interoperability

- Distributed data through service interfaces
  - Less redundant data
  - More effective data management
- Transparent / cooperative usage of services
- Based on open specifications
  - W3C, OGC
- Normalizes playing field, independent of:
  - Operating System
  - Programming Languages
  - Development Environments
Web Services

- Web Service = any software which makes itself available over the Web and uses a standard messaging system

- XML can make this happen!

- Different types of Web service technologies
  - SOAP/WSDL, XML-RPC, REST, …
Web Services Architecture Approach

Applications
- e.g., Community Water Quality, Climate Change Monitoring, Site Assessment

Services
- e.g., Water Quality Index Service
- Gazetteer service
- Web Map Service

Data
- e.g., water quality, quantity, topographic, thematic, imagery, toponymy, metadata

For Example...
- A community website which calculates water quality for a given community uses
  - Gazetteer service
  - Water Quality Index Service
  - Web Map Service based on
  - Geographical Names
  - Road network features
  - Base maps
OpenGIS Consortium (OGC)

- A global forum for the development, promotion and harmonization of open and freely available geospatial standards
- Web Services for Geospatial Interoperability
- Common data representation approaches
- “Develop first, then spec” approach…
OGC Document Hierarchy

- Abstract Specification
  - Records the basic rules – What is a feature?
  - Foundation for all that is made – many shared with ISO TC 211

- Discussion Paper
  - Early form of Implementation Specification

- Best Practices Paper
  - Mid stage form of Implementation Specification

- Implementation Specification
  - Programmer level instructions

- Profiles
  - Proper subset of Implementation or Encoding Specifications
OpenGIS Specifications

- Web Map Service
  - SLD, SE

- Web Feature Service
  - Filter

- Web Coverage Service

- Catalog Service

- Web Processing Service, ...

- Location Services

- Sensor Web Enablement Services

- Features
  - CORBA Profile
  - SQL Profile
  - OLE/COM Profile

- GML/KML
Geography Markup Language
What is GML

- The Geography Markup Language is
  - a modeling language for geographic information
  - an encoding for geographic information
  - designed for the web and web-based services

- The work is carried out by a Joint Working Team of OGC and ISO/TC 211
  - GML is an OpenGIS® Implementation Specification
  - GML is also a work item of ISO/TC 211 and is on its way to be eventually published as ISO 19136
GML enables a vendor-neutral exchange of spatial data
GML is the lingua franca of the geospatial web.

Standardized Encoding

Internet / Intranet

Web Feature Server

XML DB

Oracle

File

...
Note: GML is focused on content!

KML focuses on presentation...
Characteristics of GML

The Geography Markup Language

- Is based on XML technologies (W3C)
  - XML, XML Namespaces, XML Schema, Xlinks, …

- Is open and vendor-neutral and extensible

- Supports the definition of spatial and non-spatial properties of objects (i.e., sets of features)
Characteristics of GML

- supports the description of geospatial application schemas for information communities
- enables the creation and maintenance of linked geographic application schemas and datasets
- supports the transport and storage of application schemas and datasets
- increases the ability of organizations to share geographic application schemas and the information they describe
- leaves it to implementers to decide whether application schemas and datasets are stored in native GML or whether GML is used only for schema and data transport
GML Schemas, Application Schemas and Documents

Use a schema language to model geographic information in a **GML Application Schema** and define rules for such schemas.

Model of the Universe of Discourse in terms of the concepts of the General Feature Model

Model of structure and content of data in terms of a conceptual schema language

Data with logical structure according to the applications schema

Define standard elements and types for use in application schemas → **GML schemas**

Capture real-world objects as data conforming to a GML Application Schema → **GML Documents**
GML Schemas

- GML Schemas are horizontal and not focused on a specific application domain

- But they can provide common constructs and concepts which may be used by all the different application domains
GML Schemas

- Base schemas, general syntax, **feature model**, metadata mechanisms
- Basic geometry (0d, 1d, 2d)
- Additional geometric primitives (0d, 1d, 2d, 3d)
- Geometric composites
- Geometric aggregates
- Coordinate reference systems
- Topology
- Temporal information and dynamic features
- Definitions and dictionaries
- Units, measures and values
- Directions
- Observations
- Coverages
- Default styling
GML Feature Model

- Based on OGC Abstract Feature Specification

- Feature model of ISO 19109 matches GML
  - GML is a subset.

- Enables complex features and feature associations
GML Feature Model : Properties

- Property of a feature describes its role in the feature
GML Feature Model : Properties

- Property value can be inline
  - `<property>`
  - `<Value>`
  - `</Value>`
  - `</property>`

- Property value can be remote
  - `<property xlink:href="..."/>`

```
<position>
  <Point gml:id="P001">
    <coordinates>...</coordinates>
  </Point>
</position>
```

```
<property xlink:href="http://.../#P001"/>
```
GML Geometry

- ISO 19107 compliant
- 0D, 1D (linear, arcs, bezier, splines), 2D
- “2.5D” Geometries (2D in 3D), 3D (solids with holes)

Geometry Aggregates Primitives and Geometry Complexes

```xml
<Street>
  <name>Robson</name>
  <centerLineOf>
    <LineString gml:id="LS001" srsName="EPSG:4326">
      <coordinates>49.29,-123.135 49.28,-123.115</coordinates>
    </LineString>
  </centerLineOf>
</Street>
```
GML Geometry

<Street>
  <name>Robson</name>
  <centerLineOf>
    <CompositeCurve id="CC1" srsName="EPSG:4326">
      <curveMember>
        <LineString id="C11">
          <coordinates> 49.29,-123.135 49.285,-123.125</coordinates>
        </LineString>
      </curveMember>
      <curveMember>
        <LineString id="C12">
          <coordinates> 49.285,-123.125 49.28,-123.115</coordinates>
        </LineString>
      </curveMember>
    </CompositeCurve>
  </centerLineOf>
</Street>
GML Topology

ISO 19107 compliant

Nodes, Edges and Faces
- A node, represented by a point, can be isolated or it can be used to bound edges
- An edge is bounded by two nodes: the start (origin) node and the end (terminal) node. The order of the coordinates gives a direction to an edge.
- A face has a reference to one directed edge of its outer boundary.

Topological complexes

Topology can be described as a part of a feature or outside of features (e.g. topology of all city streets)
<Route gml:id="Bus21Route">
  <topoCurveProperty>
    <TopoCurve>
      <directedEdge orientation="+" xlink:href="#e5"/>
      <directedEdge orientation="+" xlink:href="#e3"/>
    </TopoCurve>
  </topoCurveProperty>
</Route>

...<Node id="n3"/>
<Node id="n4"/>
<Edge id="e3">
  <directedNode orientation="-" xlink:href="#n3"/>
  <directedNode orientation="+" xlink:href="#n4"/>
</Edge>
...
GML Coverage

- ISO 19123 compliant
- A coverage is a GML feature
- Gridded coverage, surface tessellation, …
- Data can be binary (file), Comma Separated Values (CSV), XML
- Easy to express things like distribution of measurement (temperature, pressure) over some geographic region.
GML Temporal Model

- ISO 19108 compliant
- Covers most of the temporal types from the ISO 19108
  - Time instances and time intervals, at different granularities
- Supports the notions of “SnapShot” and “History” to describe the time evolution of a feature
- Support for dynamic features
  - Jointly modeling feature and temporal model
  - A dynamic feature is a feature with a \textit{gml:history} property, the value of which is a set of \textit{gml:TimeSlices}
- Time stamping on feature or property level
GML Temporal Model

<gml:TimePeriod>
    <gml:beginPosition>
        <gml:TimeInstant>
            <gml:timePosition>2003-02-13T12:28:08:00</gml:timePosition>
        </gml:TimeInstant>
    </gml:beginPosition>
    <gml:endPosition xlink:href="... #T001"/>
</gml:TimePeriod>

<abc:Company gml:id="L31">
    <gml:name>General Motors</gml:name>
    <abc:location>...</abc:location>
    <abc:founded>
        <gml:TimeInstant>..</gml:TimeInstant>
    </abc:founded>
</abc:Company>
GML Default Styling

- Focuses on feature styling
- Uses Scalable Vector Graphics (SVG) and Cascading Style Sheet 2
- Capability to define styles for feature properties of different kinds
- Geometry styling and topology styling
- Ability to describe animation styles
- Parameterized styles - output depends on values of feature properties
Symbol Libraries – created separately and used in GML styles

<Feature>
  <defaultStyle>
    Inline symbol definition using SVG and CSS2
  </defaultStyle>
  <defaultStyle xlink:href="..."/>
</Feature>
GML Coordinate Reference Systems

- Complete schemas for description of all aspects of CRS

- Definitions also exist for accuracy, data quality, units of measure, etc.

- CRS defined in form of libraries and used from various applications, or referred to from the GML data directly
GML Coordinate Reference Systems

<LineString gml:id="LS001" srsName="EPSG:4326">
  <coordinates>49.29,-123.135 49.28,-123.115</coordinates>
</LineString>

Online CRS Registry

<gml:GeographicCRS gml:id="urn:epsg:v6.1:crs:4326">
  <ogc:dataSource>EPSG</ogc:dataSource>
  <ogc:revisionDate>6/2/1995</ogc:revisionDate>
  <gml:name>WGS  84</gml:name>
  <gml:scope>Used by the GPS satellite navigation system and for NATO military geodetic surveying.</gml:scope>
</gml:GeographicCRS>
Linking GML Application Schemas

- Environ-*ment*
- Cadastre, Land Use
- Road Infrastructure
- Traffic Management
- Traffic Information

GML

XML Schema / Xlink

geometry, topology, temporal, etc.

basic data types
Support for software developers

- XML Parsers, XSLT processors, etc. are available (including Open Source ones); as XML is popular in general many developers know how to work with and process XML documents

- GML Parsers (i.e. GML-aware XML parsers understanding the GML model and syntax) are emerging

- Most major GIS products have in their latest releases built-in support for GML; in addition a significant number of new products providing OGC Web Service interfaces and serving GML documents are available
OpenGIS Service Specifications

- Web Map Service
  - SLD, SE

- Web Feature Service
  - Filter

- Web Coverage Service

- Catalog Service

- Web Processing Service, ...

- Location Services

- Sensor Web Enablement Services
  - Features
    - CORBA Profile
    - SQL Profile
    - OLE/COM Profile

- GML/KML
Web Map Service (WMS)

- A widely deployed OGC specification
- Provides images of map data defined by a geographic/spatial component
- Provides point-based query functionality
- Interoperable means of map compositing from n different servers
Web Map Service (WMS)

- HTTP based (GET or POST)

- Operations
  - GetCapabilities
  - GetMap
  - GetFeatureInfo

  - Operation **keywords** are Case-Insensitive
  - Operation **values** are case-sensitive
Web Map Service (WMS)

- GetCapabilities
  - Provides XML representation of service functionality metadata, and layer metadata

- Parameters
  - Version (version of specification)
  - Service (multiple services may exist from this service URL, e.g. WMS, WFS, WCS)
  - Request (GetCapabilities)
Web Map Service (WMS)

- GetMap
  - Returns graphic image of data based on area of interest, data, etc.
  - Image, not features nor attributes
Web Map Service (WMS)

- Image format for the result
  - transparency

- How to handle exceptions

- Layers to include in the results
  - Data offerings
  - Nesting / Grouping
Web Map Service (WMS)

- **DescribeLayer**
  - OPTIONAL operation to provide more information about a WMS layer (WFS, etc.)

- **Parameters**
  - VERSION
  - SERVICE
  - REQUEST
  - LAYERS
Web Map Service (WMS)

- Typical GetMap request
- Parameters
  - version (version of specification)
  - service (multiple services may exist from this service, e.g. WMS, WFS, WCS)
  - request (GetMap)
  - format (image format to be returned)
    - Get this from GetCapabilities info
Web Map Service (WMS)

- Typical GetMap request
- Parameters
  - bbox (spatial area of interest, i.e. minx,miny,maxx,maxy)
  - srs (reference system / projection of bounding box coordinates
    - EPSG (http://www.epsg.org)
    - Get supported SRSs from GetCapabilities
  - Most widely used SRS is EPSG:4326
    - Lat/long geographic (WGS84)
Web Map Service (WMS)

- **Typical GetMap request**

- **Parameters**
  - width (output image width)
  - height (output image height)
  - layers (data desired to be visualized)
    - Get this from GetCapabilities info
    - Comma-separated list
      - Eg. Layers=elevation,roads,railways,…
      - First list item is bottom most output layer
Web Map Service (WMS)

- **Typical GetMap request**
- **Parameters**
  - Styles (desired portrayal of data)
    - Get this from GetCapabilities info per layer
  - Comma-separated list
    - e.g. layers=elevation,roads,railways&styles=default,red,blue
    - Style list MUST align with layer list
    - Empty list value for non styled layers
    - e.g. to style ONLY railways layer:
      layers=elevation,roads,railways&styles=,,blue
Web Map Service (WMS)

- Typical GetMap request
- Parameters
  - Styles and SLD
    - SLD enables remote classification and symbolization of data
    - Overrides server-based styles if request from user
    - Previous version of the standard, to use in GetMap, SLD document must exist over HTTP and cited in GetMap request
      - &sld=http://ceoware2.ccrs.nrcan.gc.ca/tkralidi/sld.xml
    - Current version of the standard support inline styling
Web Map Service (WMS)

- **Typical GetMap request**

- **Parameters**
  - `transparent` (whether to make non-opaque data pixels transparent)
    - Either TRUE or FALSE
    - Useful for layering data from multiple remote WMS services atop each other for map composition
    - Depends on image format (JPEG is not transparent)
    - Depends on web browser support
      - GIF transparency is supported in all browsers
      - PNG transparency support in newer browsers (NN7, etc.)
  - `bgcolor` (optional background color of image)
Web Map Service (WMS)

- Typical GetMap request

- Parameters
  - Exceptions (how to handle errors)
  - Can be caused by:
    - Server malfunction
    - Invalid client syntax (missing required values, etc.)
  - application/vnd.ogc.se_xml
  - application/vnd.ogc.se_inimage
  - application/vnd.ogc.se_blank
Web Map Service (WMS)

- **Typical GetMap request**

- **Parameters**
  - Exceptions
    - Which one should I use?
      - application/vnd.ogc.se_inimage
        - Useful for easily visualizing errors in your app
        - Can also be ugly to the end-user / audience
    - application/vnd.ogc.se_blank
      - Returns a blank image
      - Difficult to recognize what type or error has occurred
    - application/vnd.ogc.se_xml
      - Returns an XML exception document
      - Difficult to decode if your app is requesting an image type
Web Map Service (WMS)

- **GetFeatureInfo**

  - Performs point-based queries on map data
  
  - No ability for complex, expression-like queries

  - This is covered the WFS specification
Web Map Service (WMS)

- **Typical GetFeatureInfo request**
  - Parameters
  - `<all GetMap parameters>`
    - request=`GetFeatureInfo` instead of GetMap
    - Pass on ALL GetMap keyword-value pairs as if performing a GetMap request
    - x (pixel value in X image coordinates)
    - y (pixel value in Y image coordinates)
    - query_layers (layers to be queried)
      - Can be one or multiple layers
      - This does not substitute passing the layers parameter
Web Map Service (WMS)

- Typical GetFeatureInfo request
- Parameters
  - info_format
    - Get this from GetCapabilities info
  - Common formats
    - HTML: difficult to parse
    - GML
Styled Layer Descriptor

- “Add-on” specification to OGC:WMS
  - “SLD-enabled WMS”
  - Relies on additional OGC specification called Symbology Encoding (SE) for defining the styles

- Enables custom styling
  - Data at the server does not have to change
  - Client can sends SLD XML document for symbolization, etc.
Styled Layer Descriptor

- Additional WMS operations with SLD
  - GetLegendGraphic
    - Dynamic legend icon for a given layer
  - GetStyles
    - Returns OGC:SLD for a given layer
Web Feature Service (WFS)

- Feature level access to spatial data (vectors)
- Rich query interface
- Returns GML
- Transactional capability (WFS-T)
- Security considerations for OGC:WFS-T
Web Feature Service (WFS)

- Operations
  - GetCapabilities
  - DescribeFeatureType
  - GetFeature

- Transactional Operations
  - GetFeatureWithLock
  - LockFeature
  - Transaction
    - insert, update, and delete geographic features
Web Feature Service (WFS)

- GetCapabilities
- Same idea as OGC:WMS GetCapabilities

Parameters
- VERSION
- SERVICE
- REQUEST
Web Feature Service (WFS)

- DescribeFeatureType
  - Provides an outline of the structure of a feature type (fields, etc.)
  - Similar to SQL describe <table> command

Parameters
- VERSION
- SERVICE
- REQUEST
- TYPENAME
Web Feature Service (WFS)

- GetFeature
- Access the data!
- Parameters
  - VERSION
  - SERVICE
  - REQUEST
  - TYPENAME
  - FILTER (optional)
  - BBOX (can also be done through FILTER)
OGC Filter Specification

- “Add on” specification to OGC:WFS
- Custom XML query language
- SQL in XML, almost

Spatial and aspatial query capabilities
- Logical
- Spatial
- Comparative
OGC Filter

- E.g.:
- SQL:
  ```sql
  select * from roads where roadtype = 1
  ```
- OGC:Filter:
  ```xml
  <Filter>
    <PropertyIsEqualTo>
      <PropertyName>roadtype</PropertyName>
      <Literal>1</Literal>
    </PropertyIsEqualTo>
  </Filter>
  ```
Other OGC Service Specifications

- Web Coverage Service (WCS)
  - Querying and retrieval of coverages (i.e., rasters)

- Web Catalogue Service (WCS)
  - Discover, browse, and query metadata about data, services, and other potential resources.

- Web Processing Service (WPS)
  - Protocol for invoking geospatial processing services

- OGC Location Services (Open-LS)
- Sensor Web Enablement Services
- …
Questions?