The Application of Geography Markup Language(GML) to the Maritime Information

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Abstract

This paper describes an application of information presentation based geographic map for maritime information, including navigation information. The work is motivated by the need to prepare maritime information representation and distribution for future generation Web network technology. This works consist of map generation using GML and application to maritime information.

. GML 3.0 became an adopted specification of the Open Geospatial Consortium(OGC) in January 2003, and is rapidly emerging as the world standard for the encoding, transport and storage of all forms of geographic information. This paper looks at the application of GML to one of the more challenging areas of maritime information. Specific features of GML of interest to maritime information provider are discussed and then illustrated through a series of maritime information case studies.

The first phase of the work consists of the construction of GML application schema for using as a base map of maritime information. Maritime information is acquired from multiple sources, including standards documents, database schemas, lexicons, collections of symbol definition. The sources of GML ontological knowledge and the contribution of each source to the overall ontology are described in this paper. In the second phase, the prepared GML is used to create a prototype of the mixed maritime information as a base map – for tagging documents within the maritime domain. An overview of this prototype is included. One application area for these information elements described here is the integrated retrieval of maritime information from diverse sources, ranging from Web sites to nautical chart databases and text documents.

Keywords: GML, XML, Information, Transportation, Safety, Marine, Ontology, Schema

1. Introduction

There is an increasing demand for information from shore authorities who need a more comprehensive awareness of the vessels navigating off their coasts to promote safety at sea and marine environmental protection. And the ship master increasingly needs to have more relevant and accurate information on other ships in the vicinity. In recent years we've also seen vessels get bigger and faster.

And there are some relatively new maritime hazards for mariners to consider. Since the 1960s, we've had oil platforms and now we also have wind farms. We've also seen changes in traffic patterns, which have led to congestion on some sea routes.

Consequently, there are ever-evolving shipboard equipment, systems and practices necessitating new training requirements being placed on seafarers. Indeed, a lot of money has been spent by ship owners and operators in support of our objectives of 'safer ships and cleaner seas'.

The aviation industry has already tackled similar issues. Today, both civilian and military aircraft have sophisticated navigational abilities. And, the need for split-second decision making has driven the development of very sophisticated and - moreover - integrated information displays. And they are now common the world over. Elsewhere, we can see today's cars and lorries benefiting from sophisticated colour map displays and voice announcements to guide drivers through unfamiliar territory. In comparison, the bridge of a typical merchant ship is awash with different generations of navigation technologies - which are not always complementary. The display equipment isn't integrated or prioritized. Value added data management is either limited or nonexistent. And what information is available, visual or otherwise, needs careful interpretation by experienced professionals. In short, mariners are asked to navigate with a variety of 'bolt-ons' to previous generations of technology. And some of this can be complex and require new and different skills to operate. And only the busiest sea lanes, such as the Malaca Straits, can enjoy interactive navigation monitoring and advice from the shore. And at the other end of the scale, there is still a dependence on buoys, lights and radar transmissions.

At the same time, The MSC of IMO(International Maritime Organization) decided to include, in the work programmes of the NAV and Radiocommunications and Search and Rescue (COMSAR) Sub-Committees, a high priority item on "Development of an e-navigation strategy", with a target completion date of 2008 and with the NAV Sub-Committee acting as co-ordinator. NAV 52, which meets in July 2006, was instructed to give preliminary consideration to this important topic. The aim is to develop a strategic vision for e-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator. As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. E-navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

GML 3.0 became an adopted specification of the Open Geospatial Consortium(OGC) in January 2003, and is rapidly emerging as the world standard for the encoding, transport and storage of all forms of geographic information. This paper looks at the application of GML to one of the more challenging areas of maritime information. Specific features of GML of interest to maritime information provider are discussed and then illustrated through a series of maritime information case studies.

The first phase of the work consists of the construction of GML for using as a base map for maritime information. Maritime information is acquired from multiple sources, including standards documents, database schemas, lexicons, collections of symbol definition. The sources of GML ontological knowledge and the contribution of each source to the overall ontology are described in this paper. In the second phase, the prepared GML is used to create a prototype of the mixed maritime information as a base map – for tagging documents within the maritime domain. An overview of this prototype is included. One application area for theses information elements described here is the integrated retrieval of maritime information from diverse sources, ranging from Web sites to nautical chart databases and text documents. An architecture for such a retrieval system is described.

2. GML Elements for Maritime Information

This section introduces some fundamental elements of GML that are likely to be of particular interest to maritime information provider, including the feature framework(which in turn includes coverages and observations), geometry types, units of measure and units of measure dictionaries, time, the GML metadata mechanism, and coordinate reference system(CRS).

2.1 Features and geometry

The feature framework is used to create kinds of objects that model real world entities and is fundamental to any use of GML. Users or data administrators create domain specific objects that make up the vocabulary of the domain. Such objects might include, for example, lights, buoys, shoreline, soundings. Features in GML are named XML elements that are described by their property children. Feature properties can have geometric and topological values. Note that we do not talk about “the geometry” of a feature, but rather about geometric properties that express geometric aspects of the feature. In GML, a feature can have multiple geometric properties each representing different aspects of the object in question.

GML 3 provides a modular set of schemas for geometry starting from simple points and lines to complex curved surfaces and solids. Using GML geometry primitives, a user can encode almost any type of geometric structure. Where GML does not provide the appropriate geometry, or where the GML encoding is more complex or too verbose, the user can extend GML primitives as required to create new, specific, geometry types.

2.2 Coverages and observations

GML recognizes special feature subtypes including coverages and observations. Coverages represent the distribution of some quantity(or set of quantities) over a region of the anticipated port. The domain of the coverage is the space-time information on which the values of the coverage are defined, and is represented in GML by a collection of maritime information elements.

GML observations model the “act of observing”. Each observation has the time and nominal location at which the “result” of the observation was recorded. Observation results(some would call the result of the observation) can include numerical quantities with units, categories, a text string(e.g. qualitative observation) or a coverage(e.g. an image). Many types of observables can be represented as coverage-valued observations.

2.3 Units of measure and units dictionaries

The application of GML to the maritime information would be greatly restricted if GML did not support a flexible system of units. Units are required not only for geometric properties(e.g. coordinate values in meters), but also for coastline types, buoy types and so forth.

GML provides a mechanism to attach a unit of measure(uom) reference to any GML property. The uom attribute can be interpreted in two different ways. The data consumer can assume that the unit is well known (globally understood) and process it based on internal tables. Alternatively, the consuming program can interpret the “uom” attribute as a reference to an entry in a uom dictionary.

2.4 Time

The maritime information is dependent on time. This calls for the ability to define and use specific maritime traffic time scales, which is supported in GML using a temporal reference frame. In addition, GML allows users to describe the evolution of features in time as a sequence of time slices of time varying properties. GML also allows a time parameter to be either a time instant or a time interval.

2.5 Coordinate reference systems

For reasons of data presentation and data understanding, maritime information providers use a variety of CRSs. These can include various types of standard projections as well as many custom CRSs with user-defined reference planes or datum surfaces.

As in the case of systems of units, GML takes a very flexible approach to CRSs. Geometric objects in GML(e.g. <geml:Point srsName=”..”>) are defined relative to a CRS using the “srsName” attribute. The value of this attribute can be interpreted as a well-known name for the CRS or can be interpreted as a reference to an entry in an online CRS dictionary.

2.6 Metadata

GML provides a general framework that users employ to define particular types of objects for a given application domain. Metadata in GML is then viewed as information “about” these objects(e.g. when created, by who etc.) and is not part of the object definition.

Just as GML does not define specific geographic object types like Buoy or Light(these are defined by users), GML defines very little in terms of concrete an identifier attribute, and optional name, description and bounedBy properties. GML does, however, provide a framework by which arbitrary user-defined metadata can be attached to any GML object and be distinguished from the defining properties of the object. This is supported through the metadata property which can be optionally attached to anything derived from gml:AbstractGMLType.

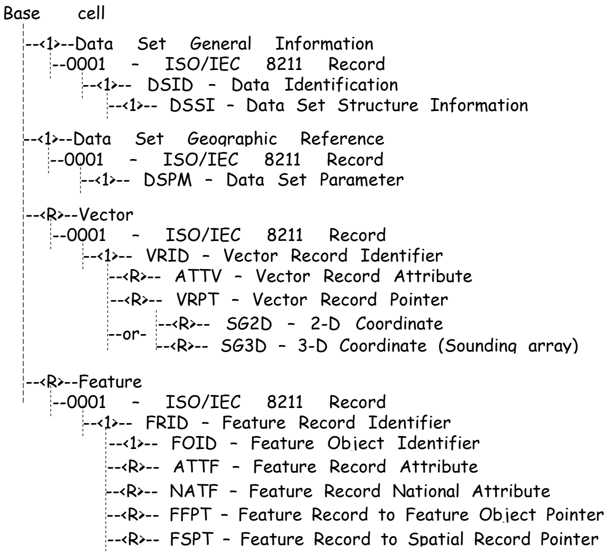
3. GML Application for Maritime Information

To better understand the application of GML to maritime information, we consider a series of case studies in which specific aspects of GML are used in particular maritime traffic domains, especially ENC(Electronic Navigational Chart).

ENCs are the new generation of nautical charts, which, in time, will replace all paper charts when sufficient ENC coverage is in place. ENC data is vector based consisting of points, lines and area features with detailed attributes; and is organized into cells, each seamlessly merges with adjoining cells without overlap. As ENCs is a one of the official and updated digital data among the marine data. it has been considering as a base map for maritime information.

3.1 Data Set Structure of ENC

The Data set file structure as specified by S-57 ENC is reflected in a GML instance document. For illustrative purposes, this data set file structure from Clause 6.3.1 of S-57 ENC is shown below:



```
Base   cell
 |
 |--<1>--Data  Set  General  Information
 |    |--0001  -  ISO/IEC  8211  Record
 |         |--<1>-- DSID - Data Identification
 |              |--<1>-- DSSI - Data Set Structure Information
 |
 |--<1>--Data  Set  Geographic  Reference
 |    |--0001  -  ISO/IEC  8211  Record
 |         |--<1>-- DSPM - Data Set Parameter
 |
 |--<R>--Vector
 |    |--0001  -  ISO/IEC  8211  Record
 |         |--<1>-- VRID - Vector Record Identifier
 |              |--<R>-- ATTV - Vector Record Attribute
 |              |--<R>-- VRPT - Vector Record Pointer
 |              |--or- |--<R>-- SG2D - 2-D Coordinate
 |                     |--<R>-- SG3D - 3-D Coordinate (Sounding array)
 |
 |--<R>--Feature
      |--0001  -  ISO/IEC  8211  Record
           |--<1>-- FRID - Feature Record Identifier
                |--<1>-- FOID - Feature Object Identifier
                |--<R>-- ATTF - Feature Record Attribute
                |--<R>-- NATF - Feature Record National Attribute
                |--<R>-- FFPT - Feature Record to Feature Object Pointer
                |--<R>-- FSPT - Feature Record to Spatial Record Pointer
```

Figure 1. S-57 Dataset Structure

In GML, the DataSet element is represented by a feature collection. Note that the fields: DSID, DSSI DSPM, FRID, FOID, VRID and their subfields are handled in GML by metadata properties, which are inherited from AbstractFeatureCollection Type

3.2 Vector Records

In the S-57 schemas the spatial requirements for s-57 ENC are extended by encoding spatial data using 2-dimensional(chain-node-face) topology, rather than just chain-node topology. Geometry and topology are merged in S-57, but are encoded separately in GML. Backpointers from each topology primitive(Node, Edge, Face) to the corresponding geometry primitives(Point, LineString, Polygon) are used in the S-57 schemas to emulate the merged topology and geometry model in S-57.

As an example, S-57 vector record encodings of two nodes, an edge and a face are represented in an instance. This example illustrates the use of all three backpointer properties: pointProperty, curveProperty and surfaceProperty and the handling of the VRID field and the MASK and TOPI subfields of the FSPT field. The corresponding S-57 record data is included inside XML comment tags (<!-- -->).

```
<topologyModel>
    <gml:TopoComplex gml:id="TC002">
        <gml:maximalComplex xlink:href="someURI" xlink:title="MaximalTopologyComplex"/>
        <gml:superComplex xlink:href="someURI" xlink:title="Group2TopologyComplex"/>
        <gml:topoPrimitiveMembers>
            <gml:Node gml:id="N120_462">
                <gml:metaDataProperty>
                    <VectorRecordIdentifier>
                        <recordName>120</recordName>
                        <recordIdentificationNumber>462</recordIdentificationNumber>
                        <recordVersion>1</recordVersion>
                        <recordUpdateInstruction>1</recordUpdateInstruction>
                    </VectorRecordIdentifier>
                </gml:metaDataProperty>
                <gml:pointProperty xlink:href="#P120_462"/>
 <!-- S-57 ENC Vector Record
 00067 D    00046   1204 0001300VRID903SG2D912
 0001:  466
 VRID: RCNM 120 RCID 462 RVER 1 RUIN 1
 SG2D: YCOO -32.552338 XCOO 60.908644
 -->
```

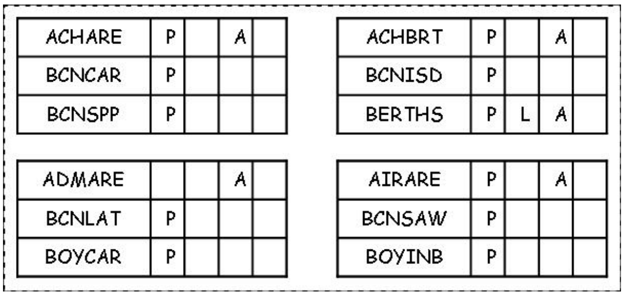
Figure 2. Sample Encoding of Vector Records

3.3 Feature Records

In general, S-57 feature records can be represented by GML Features. The exception is : C_ASOC since Associations are expressed by properties of features in GML. A sample feature record taken from an ENC data set is an Airport/Airfield (AIRARE)

3.4 Spatial Binding to Features

Section 3.3 of S-57 ENC provides the allowed geometric primitives used by each feature object. The first 12 objects and their allowed geometric primitives are listed below



ACHARE	P		A	
BCNCAR	P			
BCNSPP	P			

ACHBRT	P		A	
BCNISD	P			
BERTHS	P	L	A	

ADMARE			A	
BCNLAT	P			
BOYCAR	P			

AIRARE	P		A	
BCNSAW	P			
BOYINB	P			

Figure 3. Spatial Binding to Features

The three spatial descriptions : P = Point, L = Line, and A = Area, of a feature objects correspond to spatial properties : position, centerline, and extent, respectively, whose values are gml : Node, gml : Edge, and gml : Face. Note that some objects are allowed a choice of more than one of the three spatial descriptions. AIRARE is such an object and in this case may have a position or an extent property as shown in the following schema fragment.

3.5 Feature Relationships

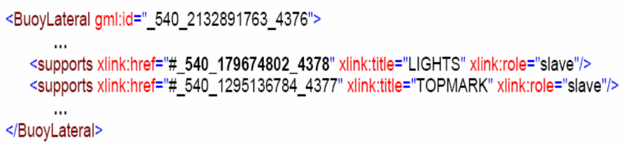
The following sample S-57 ENC feature record(Lateral Buoy) is associated to two feature records(LIGHTS and TOPMARK) as indicated by the Feature Record to Feature Object Pointer(FFPT) fields.

FRID: RCNM 100 RCID 827 PRIM 1 GRUP 2 OBJL 17 RVER 1 RUIN 1
FOID: AGEN 540 FIDN 2132891763 FIDS 4376
ATTF: ATTL 4 ATVL 2
ATTF: ATTL 36 ATVL 1
ATTF: ATTL 75 ATVL 3
FFPT: LNAM 540 179674802 4378 RIND 2 COMT
FFPT: LNAM 540 1295136784 4377 RIND 2 COMT
FSPT: NAME 110 139 ORNT 255 USAG 255 MASK 255

Note that the LNAM subfield value “540 179674802 4378” represents the concatenation of the AGEN, FIDN and FIDS subfield values of the following target S-57 object (LIGHTS)

```
FRID: RCNM 100 RCID 829 PRIM 1 GRUP 2 OBJL 75 RVER 1 RUIN 1
FOID: AGEN 540 FIDN 179674802 FIDS 4378
ATTF: ATTL 37 ATVL
ATTF: ATTL 75 ATVL 3
ATTF: ATTL 107 ATVL 4
ATTF: ATTL 141 ATVL (1)
ATTF: ATTL 142 ATVL
FSPT: NAME 110 139 ORNT 255 USAG 255 MASK 255
```

The LNAM subfield value corresponds to the gml:id value “_540_179674802_4378” of the corresponding GML target feature (LIGHTS):



```
<BuoyLateral gml:id="_540_2132891763_4376">
      ...
   <supports xlink:href="#_540_179674802_4378" xlink:title="LIGHTS" xlink:role="slave"/>
   <supports xlink:href="#_540_1295136784_4377" xlink:title="TOPMARK" xlink:role="slave"/>
      ...
</BuoyLateral>
```

Figure 4. Sample Encoding of Feature Relationships

Note that the RIND subfield value “2” indicates that the role of the target feature is slave and this is indicated in GML using the xlink:role attribute value “slave”. The optional xlink:title attribute value can store the target S-57 object name to give an indication of what the target value is without having to resolve the reference.

3.6 Attribute Values

The GML application schema supports empty attribute values, i.e an attribute may be mandatory but its value may not be supplied. The recommended schema mechanism to support this requirement is to use set nillable=”true” wherever necessary on property elements that represent S-57 attributes.

S-57 attributes of type “E” and “L” provide code, id (or possibly a list of id’s in the case of “L” type attributes) and text values information. This is handled in the S-57 schemas by creating a GML object named CategoryOfAirportAirfield that has <code>, <idList> and <value> properties. The following example illustrates both the full text value "civil aeroplane airport" and the id value "2" of the CATAIR attribute of the AIRARE object.

```
  <AirportAirfield>
     <catair>
        <CategoryOfAirportAirfield>
             <code>7</code>
             <idList>2</idList>
             <value>civil aeroplane airport</value>
        </CategoryOfAirportAirfield>
    </catair>
</AirportAirfield>
```

Figure 5. Sample Encoding of Attribute Values

3.7 Coordinate Reference System Handling

Coordinate Reference Systems (CRS) are referenced in GML using a URI valued srsName attribute on any GML geometry element (or gml:pos element). In GML3.1, the srsName attribute value only needs to be declared once (on the gml:Envelope element inside the bounding box of the feature collection) and this CRS applies to all coordinates in the document by default. If the srsName attribute also appears lower down on a geometry element in the document, then lower srsName value overrides the higher one within the scope of that geometry element. The following instance fragment illustrates the use of a URN valued srsName attribute to reference the S-57 CRS:

```
<DataSet>
      ...
   <gml:boundedBy>
      <gml:Envelope srsName="urn:x-IHO:compoundCRS,horizontalDatum:x-IHO:3.1:2,verticalDatum:x-
IHO:3.1:17,soundingDatum:x-IHO:3.1:23">
         <gml:pos>-32.548308 60.907419</gml:pos>
         <gml:pos>-32.548412 60.908543</gml:pos>
      </gml:Envelope>
   </gml:boundedBy>
      ...
</DataSet>
```

Figure 6. Sample Encoding of Vector Records

4. Maritime Information service using GML

There is lots of maritime information such as AIS Message, NtM, Port Information, Chart, Coast Pilot, Documents for Mariners, VTS, Marine Service, Communication. The bridge of a typical merchant ship is awash with different generations of navigation technologies. The display equipment isn't integrated or prioritized. Value added data management is either limited or nonexistent. It requires new and different skills to integrate the maritime information based GIS map using GML. This section describes how the GML scheme is applied to maritime information.

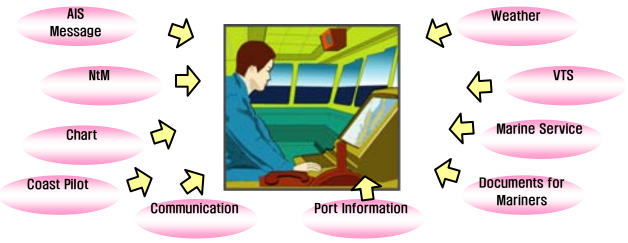


Figure 7. A flood of maritime information

4.1 Data Modeling

The markup language appears to divide naturally or intuitively into partitions or different sub-languages, each corresponding to a separate XML schema. The partition is based upon taking into account the source of the ontological knowledge, the use of markup, interdependencies, and expectations for change control. The existence of a specific source for a part of ontological knowledge usually indicates its use within sub-domains of the overall domain – for example, weather ontology(or markup) will be used by forecasters, distributors of weather information, and consumers(mariners), but the digital charts community is not interested in weather insofar as the making of digital chart databases is concerned. Change control and updating of ontologies and markup will be simplified by limiting theses responsibilities to the interested sub-communities.

In practice, this partitioning is expected to be implemented using different namespaces(or another suitable partition mechanism). Below figure contains a conceptual overview of the author’s view of a possible partitioning of different schemas.

The diagram on the left of below figure shows the conceptual structure with markup languages at the core consisting of:

1. The S-57 core, comprising entities and attributes described in the International Hydrographic Organization’s S-57 standard and only those entities

and attributes.

2. A geography markup component, tentatively identified as GML which is being prepared by the OpenGIS consortium. This is included primarily to represent low-level primitives such as shapes(lines, polygons, etc.)
3. A communications (sub)language for describing commnunications-related information(VHF channel information, radio call signs, telephone information, etc)
4. A Services (sub)language, to describe port facilities, small craft repair information, etc.
5. A Weather (sub)language, to describe wind and sea conditions, weather forecast, etc.
6. AIS Message, to identify own and other vessel
7. NtM, to transfer a changed information on fairway, coastal, harbor
8. Chart, to show a geographic map
9. Port information, to transfer an information on port facility

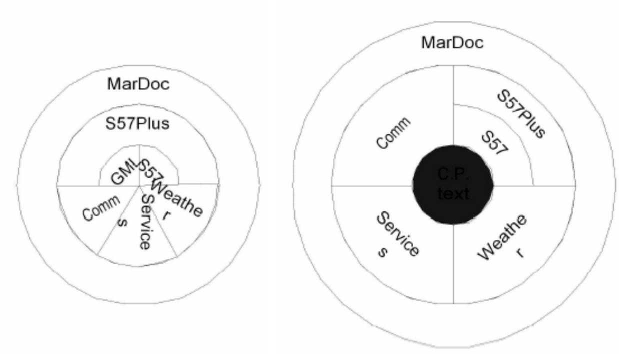


Figure 8. Diagram on maritime information

The outer components in the figure are : a sub-language tentatively called S-57 Plus, intended to extend the S-57 core with markup information that is generally required when S-57 elements are discussed in texts, but which is not contained in the S-57 standard; and a MarDoc component, intended for the markup of document structural elements that are not part of the domain itself, but which recur in target documents(for example, a “chart” element that could demarcate the part of a text document that contains information pertaining to a specific nautical chart). Layering in above Figure denotes “use relationships” – for example, elements defined in the “MarDoc” part are expected to use(contain) elements in all the other parts, but the S-57 component is not expected to use elements or definitions from other parts.

The diagram on the right of above figure illustrates the use of markup components with a specific target document or information resource(the shaded part at the center). Note that not all the components need be used to mark up any specific information resource. The formal definition of the language is envisaged to be in terms of XML Schemas.

4.2 Demo

A ‘passage plan’ is an answer to the questions: “How do I get from X to Y? What will I encounter on the way, and what will I find when I get there? What do I need to know for this particular journey?” Passage planning involves not just plotting a safe route, but also includes generating a report about hazards that may be encountered, facilities available along the route and at the destination, weather and tide conditions that may be encountered, facilities available along the route and at the destination, weather and tide conditions that may encountered during the voyage, etc. The passage plan depends on the type of vessel and the purpose of the journey, since information that may be of interest to a freighter may be irrelevant to a small pleasure craft. The use of these concepts, and of markup language is demonstrated in a prototype application.

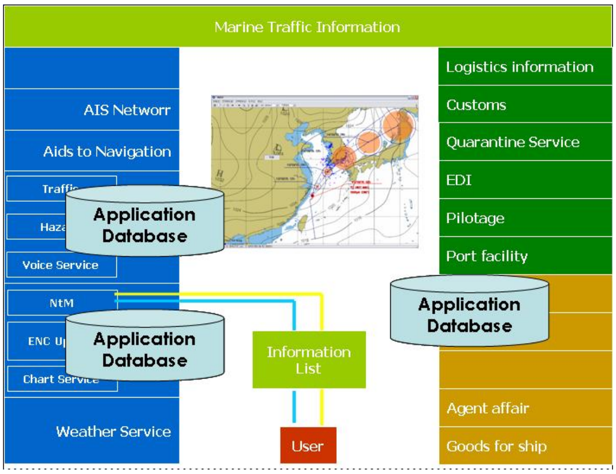


Figure 9. Demo on maritime information service

Content sources for prototype site

The ‘content’ sources for passage planning are Web sites with real time information, the Coast Pilot, and programs that generate information as when required.

Static text documents

The primary text document currently being used is the Coast Pilot, described earlier. It includes descriptions of particular items of interest, some of which are shown in nautical charts (such as lighthouses and beacons), and other descriptions which are either not available in the nautical charts and other places, or not apparent from them, such as special local tidal angers. It also contains a few diagrams and photographs taken from a mariner’s point of view, information on anchorages, etc., and pointers to other sources.

Web sites with real-time information

Certain information is being made available in near-real-time by both official and unofficial sources, especially weather conditions, forecasts, and warnings.

Dynamically generated content

Certain content(tide predictions) is generated by programs residing on the local web server.

Extraction from XML documents

Relevant elements from the marked-up coast pilot are extracted in response to a user query. Relevance is judged based on proximity to the location(s) specified (and the route between source and destination), the type of vessel and purpose of the voyage, and in response to the optional question mentioned earlier.

Real-time information presentation

Information about weather conditions is retrieved from the weather center, and processed into a form suitable for presentation, this time with markup language added automatically.

Data retrieval

The databases created from GML are queried with SQL queries and the results transformed into forms suitable for presentation. This transformation currently involves statistical post-processing of the information, the nature of this post processing depends on the form of the query, especially when the retrieval is raw material for an response to the optional user questions mentioned earlier.

Single interface for simple question answering

The prototype is able to answer questions posed using a limited vocabulary and syntax. Questions can be asked in ways that are close to natural language. Pattern matching is used to transform this natural-language question into a query that can be executed by the database back-end. The techniques used in information retrieval and processing of retrieved information may involve the capabilities described earlier in this section.

5. Conclusion

The primary purpose of this paper was describing the application of GML scheme to maritime information from computational ontologies and the use of markup language in information retrieval from documents and other sources used in the field. GML in maritime information is still in the early stages of development, and needs to go through a standards process before it can gain wide acceptance in the field. Research plans for the future include demonstrating capabilities beyond information retrieval, especially intelligent reasoning, using the retrieval and access capabilities provided by markup, this will involve drill-down markup, to lower levels than in the sample fragment, Querying of large databases of XML documents, the use of markup and ontologies in delivery of information to users, and the use of markup in updating databases(and documents) and in translating between heterogeneous databases will be investigated. In-corporation of a high-level conceptual model and description logic-based reasoning will also be explored.

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Reference

1. International Hydrographic Organization. IHO transfer standards for digital hydrographic data, edition 3.1
2. Biron, P., Permanente, K., Malhotra, A., 2004. XML schema part 2: datatypes, second ed. W3C Recommendation Document, http;//www.w3.org/TR/2004/ REC-xmlschema-2-20041028/.
3. Cox, S.A., Cuthbert A., Lake R., Martell.R., 2001. Geography Markup Language(GML) 2.0, OpenGIS Implementation Specification, OGC Document Number 01-029. http://www.opengeospatial.org/.
4. Cox, S.A., Daisey P., Lake R., Portele C., Whiteside A., 2002. Geography Markup Language Version 3.0 OGC Document Number 02-234r4 http://www.opengeospatial. Org/specs/?page=specs.
5. Raphael Malyankar, Elements of Semantic Web Infrastructure for Maritime Information, ION, 2004.
6. Ron Lake, The application of geography markup language(GML) to the geological sciences, Computer & Geosciences, 2005.
7. Michael Erdmann and Rudi Studer. Ontologies as ccnceptual models for xml documents. In Proceedings of the 12th workshop on Knowledge Acquisitton, Modeling, and Management, 1999.
8. FGDC. Spatial data transfer standard. Federal Geographic Data Committee, U.S. Geology Survey. Proposed standard, 1998.
9. W.E. Grosso, H.Eriksson, R.W.Fergerson, J.H.Geneari, S.W.Tu, and M.A.Musen. Knowledge modeling at the millennium(the design and evolution of Protégé 2000). Technical report, Stanford University, Institute for Medical informatics, Stanford, CA, 1999. Technical Report SMI-1999-0801.
10. Lake, R., 1996. Information communities support information sharing. GIS World 9(2), 72-73.
11. Lake, R., 2001. Enabling the geo-spatial web. GeoSpatial Solutions July 2001 http://www.geospatial-online.com/geospatialsolutions/article/articleDetail.jsp?id=8156.
12. W3C(World Wide Web Consortium). Extensible markup language(XML) 1.0 (second edition), 2000. http://www.w3c.org/TR/2000/REC-xml-20001006.
13. W3C(World Wide Web Consortium). Resource Description Framework(RDF) schema specification 1.0, 2000. At http://www.w3c.org/TR/2000/CR-rdf-schema-20000327/.
14. W3C(World Wide Web Consortium). XML schema part 0: Primer, 2001. http://www.w3c.org/TR/xmlschema-0/.
15. W3C(World Wide Web Consortium). XML schema part 1: Structures, 2001. http://www.w3c.org/TR/ xmlschema -1/.
16. W3C(World Wide Web Consortium). XML schema part 2: Datatypes, 2001. http://www.w3c.org/TR/ xmlschema -2/.