Integration between Location Based Service (LBS) and Online Analytical Processing (OLAP): Semantic Approach

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Abstract
Location Based Service (LBS) LBS are mobile service that has the capability to provide real time information based on the user's location. Geographical Information System (GIS) has been the heart of LBS in order to provide all the functionalities in LBS. Although mostly transparent, GIS provides the basis for most functionality, from services like geocoding, routing, location search to map presentation in LBS. In the Knowledge Discovery realm, Spatial Online Analytical Processing (SOLAP) integrates conventional OLAP with GIS data sets .Integration of these two heterogeneous data sources deals with issues such as different data model structures, different schemas and query languages. In the implementation of SOLAP, two different data model must be considered. Geographical Information System (GIS) describes its data model in a hierarchical structure, use to represent spatial features. Online Analytical Processing (OLAP) however describes its data in a multi-dimensional structure, known for fast analytical processing. Although having such differences, it is now possible to distribute the data available from these three systems (LBS, GIS, OLAP) in the web. The internet has become the main transport for data and information exchange, and a proper integration framework should be use. This paper explains the process of data integration in LBS and SOLAP using Semantic Web Technology.

Keywords: Location Based Service (LBS), Geographical Information System (GIS), Online Analytical Processing (OLAP), Semantic Web, Data Integration

1.0 Introduction
Location Based Service (LBS) is a service which exploits knowledge of a device location can well provide such services to the user, by utilizing the location information (Tilson, Kale and Ryan 2004). Services like Personal Navigation, Traffic Updates, Yellow Pages and Asset Tracking are examples of applications that can be derived from the capabilities of LBS. The nature of LBS is to obtain data stored in heterogeneous databases, mostly from GIS databases. The diversity of LBS and increasing amount of non-spatial and spatial data makes applying conventional OLAP in a Data Warehouse difficult (Pestana and Silva 2005). Thus, an appropriate method that is capable to gather data from these heterogeneous sources to support the integration in different context should be considered (Jiang and Yao, 2006). The integration should provide a "Win-Win" scenario for user, OLAP organization and LBS provider (Gruber and Stephen 2002).

Semantic Web provides a new shift in the web technology that aims to support the description of the heterogeneous resources on the web into a machine readable manner. The main advantage of Semantic Web, in terms of integration is that it provides a different approach of integrating new systems with current implement systems, which is done at the semantic layer. Resource Description Framework (RDF) (RDF/XML Syntax Specification (Revised)) was introduced to provide a universal translation of data into XML format. At the conceptual level, Web ontology Language (OWL) (OWL Web Ontology Language Guide 2004)**,** RDF Schema (RDFS) (RDF Vocabulary Description Language, W3C recommendation 2004) and many more has been used to describe domain specific ontology.

Ontology may describe the backbone structure of an application that keeps Semantic Web together (Goh et al. 1999). Ontology enforces an agreement on how the information structure can be defined. Comparing to available integration techniques like federated database, ontology provide a more comprehensive approach as it is not only focused on database development, but also applicable in additional sources such as web services. Ontology allows the

reinterpretation of content of the information source of a domain. It maps different semantics from different domain and help to share conceptualization in its definition (Mena, et al., 1998).
Geography Markup Language (GML) is an XML encoding for modeling, transport, and storage of geographic information (OGC (GML) Encoding Standard). GML provides different kinds of objects for describing geography including coordinate reference systems, geometry, topology and features. A geographic feature is an abstraction of a real world phenomenon, thus a digital representation of the real world can be thought of as a set of features. The benefits of using GML include interoperability, XML based, flexible visualization of data and effective querying capabilities.

XML for Analysis (XMLA) inherits the concepts of Object Linking and Embedding (OLE) Databases by providing standardized data access to any standard OLAP data source over the web. XMLA is built upon the open Internet standards such as HTTP and XML. It is not bound to any specific language or technology making it as a popular standard for OLAP distribution.

This paper highlights the use of Semantic Web in order to provide integration for LBS and OLAP. The integration is based on two relevant XML standards, which are GML and XMLA. Related works regarding SOLAP implementation will be discussed next. The third part describes the methodology of the integration using Semantic Web. Finally, the experimental result demonstrated in semantic storage is shown at the end of this paper.

2.0 Related Works

Several researches address the use of Data Warehouse for handling SOLAP. The main objective is to integrate GIS capabilities into analytical database. Through the integration, creation of an efficient method for spatial cube implementation, particularly the design of dimension schema and navigation of SOLAP operation is paid most attention (Bédard et al. 2001). Most previous works regard integration of GIS and OLAP to handle non-spatial data in the Data Warehouse, and opted for proprietary formats to cater for spatial data. Pertaining to these facts, this research considers another alternative to integrate data for GIS and OLAP in LBS environment, giving forth to new concept of spatial data integration.

The work of Han et al (Bédard, et al. 2001) can be considered an asset to this domain as it first introduced the basic framework to Spatial Data Warehouse implementation utilizing the star-schema at logical level. The three types of dimensions and two different measures used in spatial data warehouse described earlier have been derived from this fundamental work. In reference to their approach, the star-schema is the most common modeling paradigm in data warehouse other than the snowflakes schema (Fidalgo et al. 2004). Apart from providing information on the computation of spatial data warehouse, Han underlined several challenging issues; the first is the necessity to overcome gathering of spatial data from heterogeneous sources in different format and structures (Rao et al., 2003). Spatial data are normally stored in different organization and created in different format, using different encoding structures.

Mapcube (Shekhar et al., 2001) reports a summary of spatial patterns and trends via web which include the extension of data cube concept into spatial domain. The work proposed connection to spatial data warehouse for data analysis and claims result visualization as the main difference between conventional and spatial data warehouse (Shekhar et al. 2001). However, Mapcube does not rely on the use of metadata for definition and data transformation (Lu et al. 2003). Although it could be distributed on the web, the development of Mapcube uses proprietary technology and does not support GIS underlying standards.

Kouba (Kouba et al. 2002) initiated a project called Geographical Information Online Analysis (GOAL). Integration is the main theme of this research with arguments on GIS integrations to have twofold processes instead of one (Kouba et al. 2002). GIS is not only the source for data, but it is also the tool for visualizing generated data. The study shows implementation of Integration Module (IM) for GIS and OLAP inside the data warehouse. GOAL is the first project that highlights the use of metadata in spatial data warehouse. IM does all the processing based on description provided by metadata.

Another project SIGOLAP, has proposed a three-tier architecture consisting data layer, middleware layer and application layer with particular interest to the middleware layer. The layer consists of a conceptual model of the integrated source, and a mediator. The integration metamodel is based on Common Warehouse Metamodel (CWM) (Common Warehouse Metamodel (CWM)) for data warehouse and GeoFrame for GIS (Fidalgo et al. 2004). The integration were done at data level and semantic between the metadata is not addressed clearly. Some of its limitations are the limitation to the Windows platform

Up to date, GOLAPA (Silva et al. 2004) is the most complete platform for GIS and OLAP integration. GOLAPA has been studying a method to combine query with abstraction and spatial data support together. The work aims to provide an open technology to facilitate decision support in spatial multidimensional context. Integration tools based on Web Services, Java and XML technology is make available to achieve openness. In the discussions, the architecture prepared covers every aspect for multidimensional analysis on the web which also considers the use of standard specification in GIS and in OLAP. Table 1 summarizes the comparison between all the existing systems.

Table 1: Basic Comparison between Existing System and the Integration Process

Projects	**Spatial Operations**	**Platform**	**Metadata**	**Data Warehouse**
Han	Yes	-	No	Yes
Mapcube	Yes	Web	No	Yes
GOAL	No	Windows Solution	Yes	No
SIGOLAP	Yes	Windows Solution	Yes	No
GOLAPA	Yes	Web Service	Yes	Yes

2.1 Mediator Based Architecture

In the previous work regarding SOLAP, there are a few requirements that have been seen as an important element towards the development of the framework. First, the framework should consider having spatial operations. We focus on defining spatial dimensions, as the information generated from it can be manipulated as spatial measure.

The second criterion is to consider the development platform for the framework. Here we consider the use of Web Service architecture for developing the framework. The Web Service architecture provides the freedom of developing the application, as it is loosely coupled from the Web Feature Server (WFS) architecture. WFS are server technology used to generate GML-based data. The Web Service also allows reuse of currently available components, in this case the WFS and the XMLA component.

Third, we underline the importance of metadata in this framework. Integration of both GIS and OLAP metadata will accelerate the integration process. As we are developing the application in a distributed environment, we choose to apply Semantic Web in terms of metadata management and data gathering. We identified that the main sources use in this project are semi-structured data. XML pipeline from request and responses of each component (WFS and XMLA) will be described in hierarchical model. For instances, RDF will be use to provide a standard instance encoding of the data. The metadata will use RDFS and OWL as there are needs to distribute the content for future use.

Lastly, it is not necessary to implement a spatial data warehouse for OLAP integration. In this scenario, implementing data warehouse might cost a lot of trouble, especially in terms of modifying the legacy data warehouse. The research will use mediator (Gardner, 2005) based integration as the data source could come from different organizations. Figure 1 show the mediator architecture used in this research. Client will access the system through a mediator that developed using web service technology. The mediator will formulate user request and post queries to both WFS and XMLA Server. The generated real-time request from both servers will be stored temporarily in a semantic storage and integrated using rules defined in the metadata.

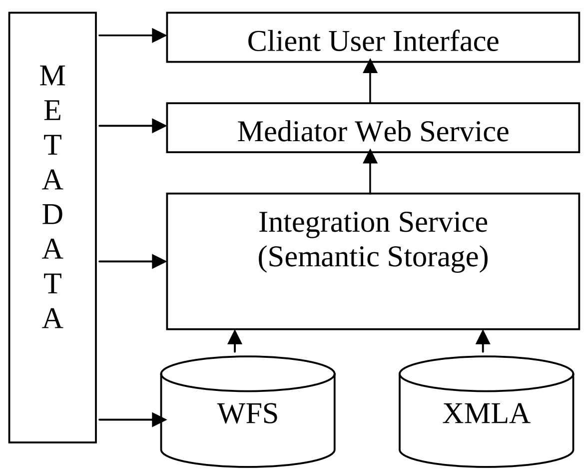

Figure 1: Mediator Architecture for SOLAP

3.0 Methodology

This part underlines the steps taken in achieving SOLAP integration in LBS using Semantic Web. The integration processes were done according to the proposed framework defined above. Methods described contain issues regarding data gathering, normalization of data, metadata mapping and query definition. Final testing was conducted to ensure that the framework can provide the integration in a homogenous environment. An overview of all the methods involved can be portrayed in figure below.

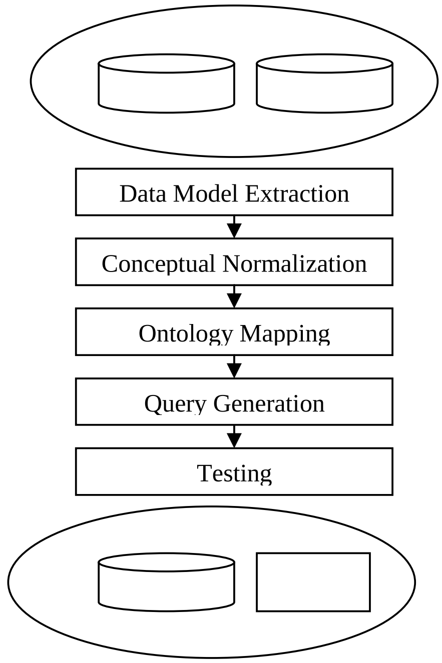

Figure 2: Method Overview

3.1 Data Model Extraction

In order to identify the data model structure for each data source, the XML pipelining technique was used for data gathering. The XML pipeline technology enables message extractions from any client or servers. In a typical web service data processing, all XML requests received over the web is passed to a pile of code for processing. This way of approach in data gathering from each WFS and XMLA servers is necessary in the early part of the methodology. The web service is able to provide standardization for communication between its clients and servers by extracting encoded messages from the WFS and OLAP servers using XML. Data derived were presented in an XML hierarchy; a model that is known to portray data in a tree structured form. This structured tree-formation depicts hierarchical attributes recognized as parent and child relations. Such relationship allows for repetitive display of recorded data as each parent can have many children but each child can only have one parent.

Using XML pipeline, generalization of the Extensible Stylesheet Language (XLS) i.e. XML for Location) request and response is done by encoding them into a WFS request and response (Open Location Service (OpenLS) Core Service, 2007. This method of generalization has been successfully used in several projects such as GIMODIG (Sajarkoski et al. 2005) VirGIS (Boucelma and Colonna 2005) and CRUMPET (Zipf 2002). The XLS request is first converted into a WFS request. The WFS provide the connection between LBS and spatial data sources. The use of WFS can be seen as a way to provide common interface for GIS-based system, as it returns data encoded in GML. Figure 3 shows the interaction between XLS and WFS.

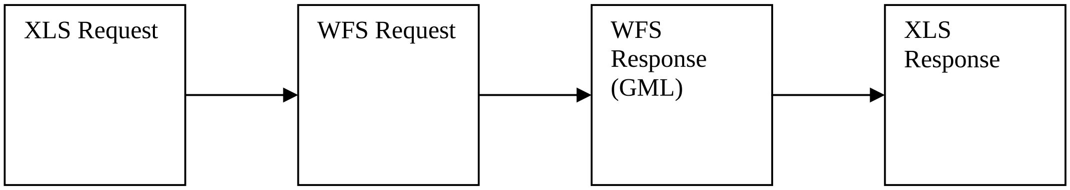

Figure 3: Interaction between LBS and WFS

By leveraging this technology, LBS can now gather data from different organizations, such as weather data from meteorological department, traffic data from municipalities and others. The GML schema can now be considered as a main data model for LBS data source in this research. Below is an example of WFS message extracted from the response message, which contains data from the server.


```
<wfs:FeatureCollection xmlns:wfs="http://www.opengis.net/wfs"
xmlns:topp="http://www.openplans.org/topp" xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<gml:boundedBy>
<gml:Box srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
 <gml:coordinates decimal="." cs="," ts="">-75.791435,38.44949 -
5.045998,39.840008</gml:coordinates>
 </gml:Box>
 </gml:boundedBy>
<gml:featureMember>
<topp:states fid="CA">
<topp:the_geom>
<gml:MultiPolygon srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
<gml:polygonMember>
<gml:Polygon>
<gml:outerBoundaryIs>
<gml:LinearRing>
 <gml:coordinates decimal="." cs="," ts="">-75.70742,38.557476 -75.71106,38.649551 -
75.724937,38.83017 -75.752922,39.141548 -75.761658,39.247753 -75.764664,39.295849 -
75.397728,39.073036 -75.324852,39.012386 -75.307899,38.945911 -75.190941,38.80867 -
75.083138,38.799812 -75.045998,38.44949 -75.068298,38.449963 -75.093094,38.450451 -
75.350204,38.455208 -75.69915,38.463066 -75.70742,38.557476</gml:coordinates>
 </gml:LinearRing>
 </gml:outerBoundaryIs>
 </gml:Polygon>
 </gml:polygonMember>
 </gml:MultiPolygon>
 </topp:the_geom>
<topp:STATE_NAME>California</topp:STATE_NAME>
</topp:states>
 </gml:featureMember>
 </wfs:FeatureCollection>
```


Figure 4: Sample of Generated Result from WFS Server

For XMLA Service, the schema can be extracted in a more straightforward manner. The descriptions of data sources are provided in the XMLA schema. XMLA response will return the results from OLAP server in XML row set which is extracted from the cube. It also contains information on the construction of dimensions and measures. From the XMLA response, instance and the structure of the message can be obtained.

3.2 Conceptual Normalization

Based on results obtained from the earlier stage, application of normalization techniques is considered on the collected data. In this phase, conversion of data models into ontology is done utilizing a three-tier architecture approach for ontology development.

The generated XML from previous result only provides logical constructions for the XML messages for both systems (Fodor and Werthner 2004). These schemas have been derived from different domains and the semantic behind each schema are yet to be presented. Thus, generation of a schema that provides richer definition towards both data model is required. The description is considered similar to a metadata for both LBS and OLAP data sources, defining specific rules for every element and attributes to help integration processes. This generation of a normalized ontology provides definition of the concepts involved at similar abstraction level (conceptual level). The ontology will use semantic web standard, OWL and RDFS. Accordingly, RDF format is taken as the main encoding for representation of the data instances.

An ontology infrastructure for the integration of GIS and OLAP should be able to support construction, maintenance and accessibility of other ontologies in many different domains. Guarino's (Guarino 1998) arguments classify ontologies to be different from one another based on their extensibility and reusability for specific applications or tasks. The classification is set apart between three levels of ontologies; the top-level ontologies, domain ontologies and application ontologies. Top-level are ontology were general ontology created by certified organizations. For the creation of domain ontology, the XML schemas for both data sources are considered as the best input for this process. The research chooses to implement OGC's RDFS encoding for GML. Referencing to this type of ontology is preferred due to its reusability and modularity. For XMLA, a different approach was done considering that there are no existing ontology encoding for XMLA. A summarization for XMLA Schema conversion into OWL format can be portrayed by the following table.

Table 2: Comparison between XML Schema Elements and OWL Classes and Properties (XML2OWL)

XSD	OWL
xsd:elements, containing other elements or having at least one attribute	owl:Class, coupled with owl:ObjectProperties
xsd:elements, with neither sub-elements nor attributes	owl:DatatypeProperties
named xsd:complexType	owl:Class
named xsd:SimpleType	owl:DatatypeProperties
xsd:minOccurs, xsd:maxOccurs	owl:minCardinality, owl:maxCardinality
xsd:sequence, xsd:all	owl:intersectionOf
xsd:choice	combination of owl:intersectionOf, owl:unionOf and owl:complementOf

Based on the description given in the table above, the translation process for XMLA message obtained before is completed. The summarization of the translation is shown in Table 3 and Table 4 below.

Table 3: Summary of OWL Translation 1

Name	**Type**
Axes	Class
Axis	Class
CrossProduct	Class
Tuples	Class
Members	Class

Table 4: Summary of OWL Translation 2

Name	**Type**	**Domain**	**Range**
has Axis	ObjectProperty	Axes	Axis
hasTuples	ObjectProperty	Axis	Tuples
Name	DataTypeProperty	Members	xsd:string

After defining the domain ontology for both systems, the creation of application ontology was done using notation method (Rodrigues, Rosa and Cardoso 2006). This notation allows conversion of XML node into ontology concept with three classifications of mapping identified. The notation provides guidelines and rules to convert application specific data and bind it with its domain ontology. This will allow customization of data from different servers although all were using the same data model. Basically, the notations define 3 different types of mapping:-

a) Class Mapping- Maps an XML node into OWL concept
b) Data Type property mapping- Maps XML node into data type property
c) Object property Mapping- Relates two classes mapping to an OWL object property

Table 5: Basic Notation Mapping (Excerpt from Rodrigues et al. 2006)

Mappings	Notation
Class	(OWL Class URI, XPath expression) (OWL Class URI, XPath expression, ID XPath expression)
Datatype Property	(OWL Datatype Property URI, Domain Class Mapping, XPath Expression)
Object Property	(OWL Object Property URI, Domain Class Mapping, Range Class Mapping)

For the use of semantic web, instances are defined in RDF format. The response from both servers (WFS and XMLA) will be converted into RDF, carrying the initial value obtain from the server. From the generated ontology (domain and application) the defined vocabulary is used to provide semantics meaning for the instance. Therefore, an algorithm that determines how the ontology specifies an interpretation of XML labels and their data are needed. Klien (2002) introduced an algorithm that annotates syntactic data without any additional change in XML and RDF structure. Thus, the generation process can be done remotely. This algorithm is adapted in this research. Below is a sample of GML data conversion into RDF. Notice that the structure is almost similar to XML, except that it is more loosely coupled with the addition of <rdf:Description> tagging. The sample also shows the usage of both domain and application ontology, which can be differentiate by their URI for instance encoding in Semantic Web.

```
<gml:FeatureMember>
<rdf:Description
rdf:about="http://www.xyzcorp.com/camb/example_profile3_schema.rdf#USA">
<gml:name>
United States of America
</gml:name>
<gml:description>
Sector that intersects with user's location
</gml:description>
<gml:outerBoundaryIs>
<rdf:Description rdf:about="http://www.opengis.org/gml#LineString">
<gml:coordinates>
427748.37855167,4920565.81310335 427748.37855167,4920787.3380126
428515.46470899,4920787.3380126 428517.05615694,4920782.8889182
428537.43988404,4920721.39143584 428547.07927602,4920708.10414043
428558.93680012,4920695.66667204 428575.6676182,4920687.03842829
428513.25482272,4920656.16471254 428320.45049139,4920610.17407381
428295.4325998,4920599.06633476 428213.37820321,4920581.37993477
428191.64215765,4920579.51031533 427927.56899407,4920565.82310132
427902.84795287,4920569.61233003 427839.19828075,4920567.36278792
427818.20436117,4920565.90308504 427748.37855167,4920565.81310335
</gml:coordinates>
</rdf:Description>
</gml:outerBoundaryIs>
</rdf:Description>
</gml:FeatureMember>
</rdf:Description>
```

Figure 5: Sample of GML in RDF

3.3 Ontology Mapping

With models data converted into ontology, the next step in the methodology deals with giving a sense of organization to the ontology through a concept known as ontology mapping. In this process both ontology inputs from the WFS and OLAP servers are analyzed and relating attributes between them is used to match classes and properties from both sources.

This research underlines two different challenges in terms of ontology mapping. The first one is the discovery process of the mapping, which provides method on how to discover the relations between our two ontologies. A method based on similarity (Bisson 1995) of the structure and syntactic will be use to provide the extra definition. Second, is regarding the representation of the merged ontology concept. Here the extra definition provided in the previous method will be represented in a way to facilitate the integration process. Here we use Semantic Bridging for mapping representation.

The approach for identifying similarity used in this research was adapted from Ehrig and Staab (2004). It identifies similarity based on manually encoded mapping rules. The mappings that are not yet encoded through rules serves as a platform for the basic structure of a complete mapping rule. Using these rules, possible mappings for LBS and OLAP metadata can be defined. To specify the manual rules available, the characteristics of available features were evaluated. The features of ontological entities such as concepts, relations and instances need to be extracted from external and internal ontology definitions. Then, the extracted features were grouped into a Semantic Stack, where it provides similarity studies from lower to higher level of ontology definition. Comparing entities of different ontology makes it easier to find a matching pattern for ontology mapping representation.

Semantic Bridging makes use of the similarities computed in the previous phase and is responsible for generating relevant relations between ontologies. It bridges entity in a way that each instances represented in the source ontology is translated to the most similar instance of the mapping ontology. The semantic bridging process for this research relies on the creation of SOLAP ontology. The ontology represents basic concepts of a cube similar to an OLAP cube, but with additional feature for integrating GML instances from the WFS. The basic idea for this approach can be portrayed in Figure 6 below.

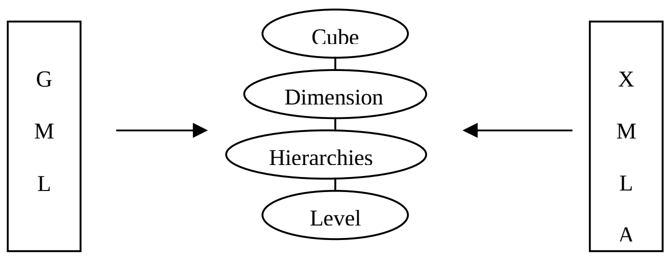

Figure 6: Semantic Bridging Using SOLAP ontology

3.4 Query Generation

To make use of the integration system, the definition of a query is an important aspect. The definition of ontology mapping defines the global schema that provides the whole structure of the integration. The query generation phase is important to distribute queries from global schema definition to different data sources. In this work, the Query Execution Plan (QEP) for the integration system is generated. Among QEP main functionalities include the generation of a plan that computes user query from relevant information sources. Starting from a global query posed to the global schema, the query is rewritten (Bertossi and Bravo 2005) in terms of sources relations to obtain the data from the sources. After the generation of views from each data sources, the data is then merged according to the mapping provided inside the metadata. Figure 7 below shows the QEP for the integration of LBS and OLAP.

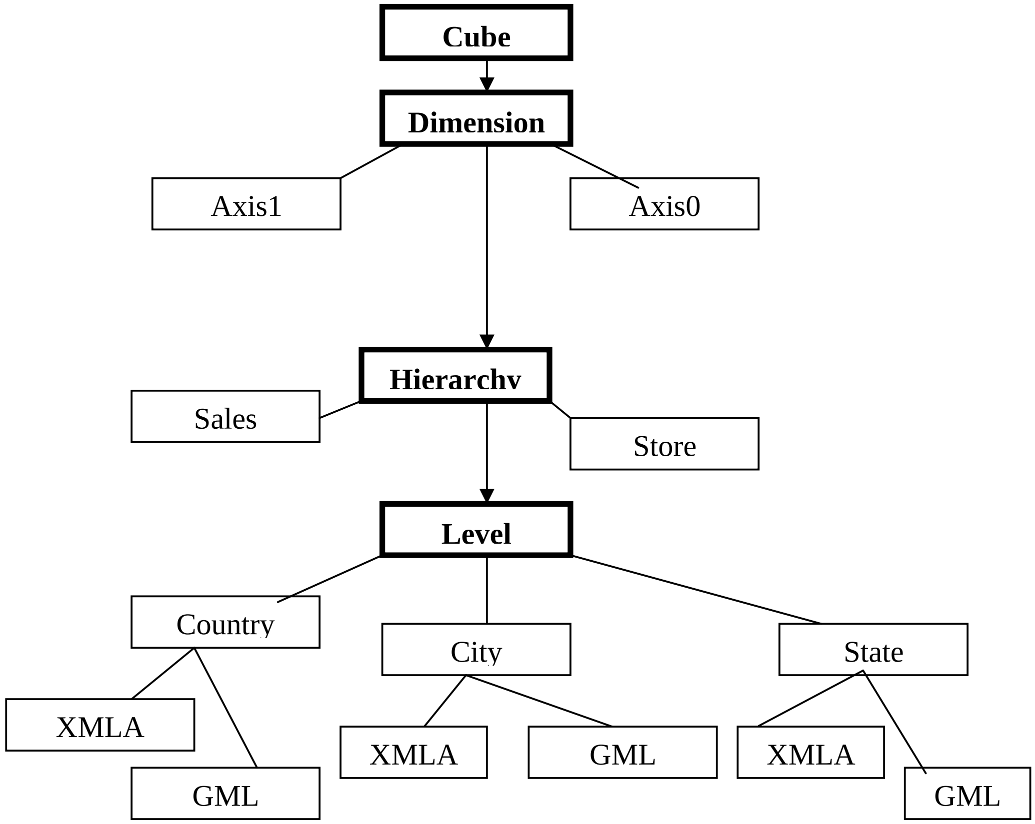

Figure 7: QEP for the Integration

3.5 Testing

The final phase in this research is to test the outcome of the whole procedures describe above. The development of a prototype will highlight the compatibility of the output from each source with the proposed framework. The final method for conducting this research is to run a test on the proposed framework. For this, a prototype was developed based on web service technology. A client which connects to the web service was used to communicate with the service. The testing phase was design to make sure that the concepts fulfill the following requirement:-

a) Client interaction with the mediator
b) Validation of SOLAP integration result

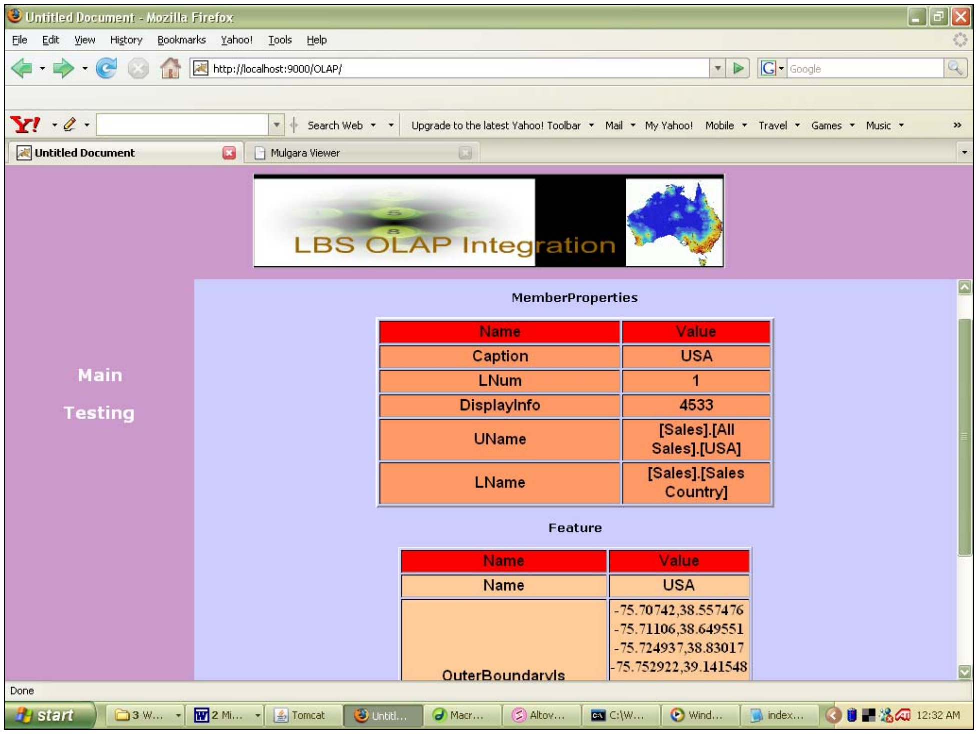

Figure 8: Data for GML and XMLA in a Single RDF

The testing for interaction with mediator has been conducted by the creation of a schema management system. The client, which is a web-based application, communicates with the web service by sending iTQL (Bertossi and Bravo 2005) query through Simple Object Access Protocol (SOAP). The client manages all ontologies by allowing operation such as update and delete. New data source can be added through the add function provided. From the test conducted on the prototype, it is to be concluded that the web service technology can serve as a basis for the integration of LBS and SOLAP. The web service supports efficient distribution of architecture which supports the reuse of components. It can reside anywhere, by allowing its client to access its metadata which is the WSDL.

As a proof of concept, the prototype will display all the data that has been integrated at particular levels. Figure 8 above shows the data from *MemberProperties* and GML *feature* of USA, portraying the integration done on the country level of the SOLAP. The coordinate displayed in the *OuterBoundaryIs* Column are spatial coordinates for generating maps. This shows that the data encoded in RDF can be reused to generate the same information as it is in native XML.

4.0 Results

For this part, we show the result of the integration process stored in semantic database, Mulgara (Bertossi and Bravo 2005). Basically the semantic storage stores data as triples, which is very different from the relational database. It provides an efficient way for storing Semantic Web data, from ontology to instances. Mapping was done for every XMLA MemberProperties element and GML feature element. In this research, we assumed that the two data sources provide the same name element based on string instances. Without this assumption, further processing towards the data has to be done such as providing a geocoding and reverse geocoding feature, or using an address ontology that can facilitate or do extensive reasoning towards both data. Figure 9 shows the output of a combined USA data from WFS and XMLA

Server. Notice that two different URI were used in the left display. The First URI shows that the data related to USA, a member of the Country hierarchy. The same URI were used to describe XMLA instances such as LName, LNum, Caption and UName in the middle. This information can be use to generate a tabular information, similar to the XMLA response. The GML based data were shown by the other URI. Basic information such as Name, Description and others can be shown directly. The coordinates to generate the polygon for USA can be obtained in the linestring definition.

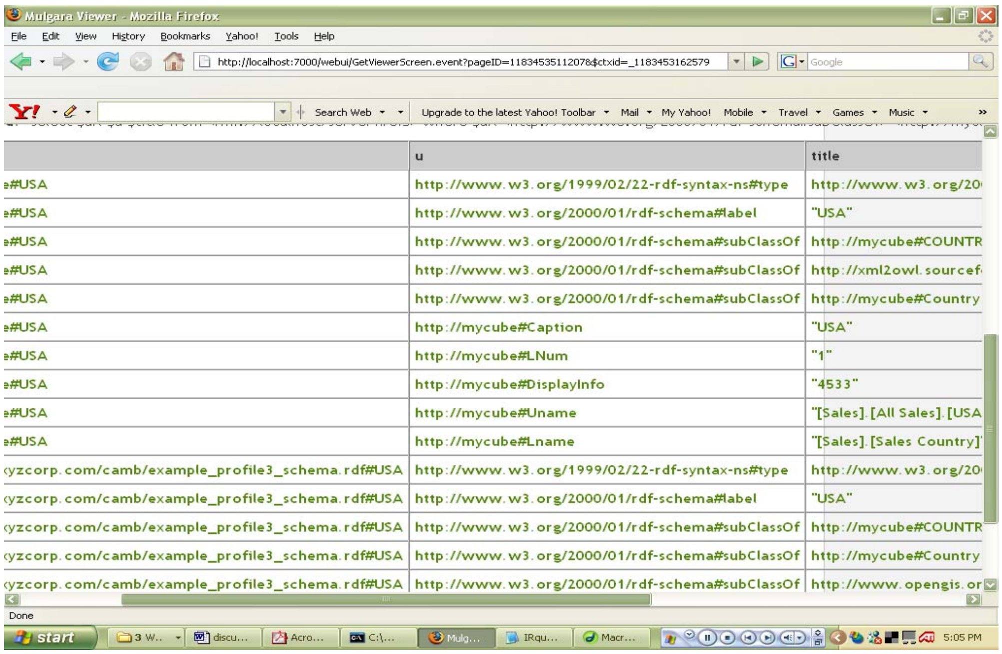

Figure 9: Integration Result in Semantic Storage

Currently the research describes a method to enable semantic integration between GIS and OLAP. The integration was done basically based on instances, which is quite simple and straight forward. For handling complicated data and additional description towards the ontology should be considered. Information such as Address and postcode ontologies might provide some enhancement together with some reasoning capabilities through the use of Description Logic in the semantic layer. The hierarchies used for OLAP generation only consider full containment between each spatial attribute. In the future there might be a need to use partial containment for analysis in LBS. Partial containment tackles issues such as geometry overlapping rather than adapting contain and within relation. Using partial containment enhances the power to use spatial analysis in the SOLAP queries, as it provides different alternative of data modeling.

5.0 Conclusion

The use of Semantic Web technology has been stressed out towards all the integration process in this research. The main objective of utilizing Semantic Web is to add richness towards the data representation adopted by the usage of different standards which facilitates the integration. The research specifies method to achieve interoperability between two different system; LBS, which is a public service through WFS and private OLAP data sources containing private data belongs to an organization. Semantic Web acts as a backend processor which enables the data to be distributed and integrated in the web environment.

The expressiveness of Semantic Web can be seen as it is used throughout each and every level of the SOLAP integration. The extraction of metadata, from XML schema of respective services were done and encoded in ontology format (OWL, RDFS). Depending on the level of interaction and complicity of the system requirement, the best formal way has been adopted for ontology encoding. This is because different ontology languages have different levels of expressiveness and description. Instances were encoded in RDF, for homogenous description. The creation of global and local data sources together with instances allows data from both different servers to be encoded in a similar structure. Thus, we believe that homogeneity of both data was already achieved at this point.

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