# MEDIATOR BASED ARCHITECTURE TO ADDRESS SPATIAL DATA HETEROGENEITY

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The heterogeneous data on the web is an increasingly important field of data sharing and integrating with diverse sources for retrieving suitable information using search engines. These heterogeneous data sources from distributed systems are easily interpretable to humans, but hardly understandable to machines. In this regard, the main focus of this research is to address the issues of spatial data heterogeneity where data are located in various distributed systems in different formats. Then we describe these geo-data in a machine understandable format using rich semantic Resource Description Framework (RDF) which allows a single point of access to retrieve appropriate information from the web of data. Moreover, we performed a number of experiments to retrieve specific information from Water and Sewerage Authority (WASA) and Power Development Board's (PDB) data-sets of Bangladesh by using semantic search engine, known as SPARQL to address the interoperability issues in an efficient way which represents the effectiveness of our system. Therefore, this paper also concentrates the investigation of the design and implementation of a mediator kit, *Integration Mediation Kit* (IMK) which integrates and merges data from diverse sources.
**Key words**: Data integration, Mediators, Ontology, Semantic Web and Integration Mediation Kit.

## 1.Introduction

In the traditional World Wide Web (WWW), identical spatial data reproduced from various data sources of different organizations those are developed independently on the web to meet their requirements. These disparate data sources scattered on the web, causing spatial data heterogeneity, are essential for making decisions about these organizations. These expeditiously growing heterogeneous data in unstructured or semi-structured format are insufficient for even developing smarter method in finding specific information on the web. These information are easily readable by humans, however it is hardly understandable to machines. To develop these web contents using traditional technologies such as, Hyper Text Markup Language (HTML[1]) and Dynamic HTML (DHTML[2]), we use predefined tags to define the style of sequence of characters in a document rather than defining the meaning of these characters. However, the DHTML is the collection of technologies used to create interactive and animated web pages by using the combination of static markup language, a client side scripting language, a presentation definition language such as Cascading Style Sheet (CSS) and the Document Object Model (DOM). Although these technologies create web pages more interactive, they are incompatible to define the semantics of data in a document.

[1] http://www.w3.org/html
[2] http://en.wikipedia.org/wiki/Dynamic HTML

As a consequence of using these technologies, the traditional search engine retrieves millions of web page links for a user query rather than the more specific one. Data representations using these technologies are easily interpretable by humans rather than by machines. Furthermore, Extensible Markup Language (XML[3]) is a semi-structured data representation technique where user defines their tags to represent data in a hierarchical order. The inadequacy of uniqueness in these user defined tags to represent information is scarcely understandable by machines. However these are insufficient for developing a robust technique to find more specific information on the web.

Therefore, we use structured database in the backend for a specific domain to originate the dynamic web so that users retrieve and update their domain data. Moreover, the database schema structures are restricted to define their attributes and their respective constraints. The representations of these database schemas are not adequate to develop meaningful associations among data. Moreover, these structured data representation readable by humans or machines effortlessly but machines are impotent to extract the meaning from these data on the web. As a result of the deficiency of the semantics, the traditional search engines do not attain specific information on the web. Considering a query related to keyword *WASA*, traditional search engine retrieves *WASA* related data by searching throughout the web those are available in documents of different scattered and unstructured sources then feedback relevant and irrelevant documents to search keyword as well.

Moreover, many activities in business world involve different organizations that have to work together, and use existing spatial information whenever possible, in order to reach a common goal. Information of many organizations maintain their data in many distinct independent databases on different platforms using various data models resulting in mismatches that hamper information interchange and interoperability [T. Berners-Lee et al.,(*1999*)]. Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged [D. J. Abel et al., (*1998*), R. Laurini,(*1998*)]. When Inter-operation between these multiple heterogeneous data sources is required, there would be a number of conflicts arising not only from different database designs, but also from different kinds of data models employed within heterogeneous databases. These conflicts generate the difficulties of homogenization in terms of data model, schema and semantic [C. H. Goh et al., (*1994*), R. Holowczak and W. Li, (*1996*), W. Kim et al., (*1993*) and R. J. Miller, (*1998*)]. However, the new economic challenges force enterprises to integrate their functions and therefore their information systems including databases they are based on. These data integration rely on the Database Management System (DBMS) [L. M. Haas et al., (*2002*)] is concerned with the problem of combining data residing in different autonomous sources and providing users with unified and possibly enriched views [R. M. Soley and W. Andreas, (*1992*)] of these sources and the means to specify information requests that correlate data from many such sources. A data integration system provides the means to define such integrated views and to process information requests against these views. Database technology presents a high level of abstraction of large data sets and the operation to manage and query such data sets through declarative interfaces. In spite of this high level of data abstraction, DBMS have not enough constructs to express data semantics on the web. In this regard, Ontology is employed as a method for identifying categories, concepts, relations, and rules that prescribe theories of the domain of interest [D. M. Mark, B. Smith, and B. Tversky, (*1999*)]. However, a lot of efforts has been made to develop the next generation web, Semantic web, is a term coined by Berners-Lee et al. [T. Berners-Lee, J. Hendler, O. Lassila et al., (*2001*)] define the objective of data on the web to achieve the semantic interoperability among metadata associated with the web information. In spite of the growth of semantic web technology addresses the issue of integration and machine understandability of the huge WWW repository, information of different local community environments such as water and power supply utilities is a motivated complication problem with vast application areas such as seeking related distinguishing information from interoperable web of data. In this regard, the main center of attraction of our research is to describe data using Resource Description Framework (RDF[4]) which integrated all resources and instances by comprising of their concepts and relations for WASA and PDB, coined repository name *KB-wasa* and *KB-pdb* respectively.

[3] http://www.w3.org/XML/
[4] www.w3.org/RDF/

Moreover, we develop a central bridge in where we examine the common data on the web by focusing on the semantic mediator architecture. Therefore, we designed a mediator kit, *Integration Mediation Kit* (IMK) which addresses heterogeneity and merges identical data from diverse sources to solve the interoperability issues. We performed a couple of experiments to retrieve and inference specific information using a SPARQL[5] that shows effectiveness of our proposed knowledge repositories for WASA and PDB respectively.

The rest of research paper is organized as follows. Section II introduces general terminologies to comprehend consequent contents of this paper. Our present structure of domain of interest is articulated in Section III, while Section IV focuses the approach of our system and describes the process of making machine understandable data. Section V includes the utilization of our proposed methodology and integrates and merges data using Integration Mediation Kit (IMK). Concluding remarks along with some future directions of our work are described in Section VI.

## 2. General Terminologies

This section familiarizes some basic terminologies with their notion to readers those are used throughout this paper. It includes the theme of Semantics and Semantic Conflicts and Ontology and Interoperability to comprehend the essence of mediator based architecture to address spatial data heterogeneity.

### 2.1. Semantics and Semantics Conflict

Semantics describe the concept or meaning of information systems. A collection of primitives, *components of information system*, along with a collection of rules represent more complex ideas constitute a programming language [J. G. Brookshear, *(2000)*]. Moreover, semantics determine how the constants and the variables are associated with things in application domain [J. F. Sowa et al., *(2000)*]. Therefore, semantics can have different interpretation in propositional, first order and probabilistic logic [S. J. Russell, P. Norvig et al., *(1995)*]. In propositional and first order logic, a sentence is true or false depending on the real interpretation of the world. On the other hand, the probabilistic logic represents a sentence in favor of a degree of belief. These semantic conflicts can cause a situation of uncertainty. This can be seen as a bottleneck to develop effective information systems. Hence, the removal of semantic conflicts could help to address uncertainty issue. The semantics may be of different types such as semantics in database and semantics in programming languages [J. F. Sowa et al., *(2000)*]. In database, semantics is related to the meaning of schema (organization of the components) elements (such as, classes, attributes and methods).In database, syntax refers to the definition of the structure of schema elements. On the other hand, people's interpretation according to their understanding of the world can be seen as an example of context dependent semantics [P. R. Visser et al., *(1999)*].

### 2.2. Ontology and Interoperability

Interoperability is the sharing and exchange of information between two or more systems [F. T. Fonseca, *(2001)*]. The interoperability issue overcomes by ensuring the use of same data model to represent the information. Unfortunately, all local communities usually don't use same data model to store and retrieve similar spatial data. Moreover, research on interoperability solutions promises a way to move away from the platform dependent systems that dominate the GIS market [M. Sondheim, K. Gardels, and K. Buehler, *(1999)*]. Semantic conflicts resolution makes a system interoperable because interoperability allows the exchange of information between two or more systems and also the integration of data from various systems [A. Geraci et al., *(1991)*]. Furthermore, in the semantic web, an Ontology is an explicit, formal specification of a shared conceptualization of a domain of interest [W. W. W. Consortium et al., *(2008)* and R. Studer et al., *(1998)*]. It represents knowledge in a formal way by defining

[5] http://www.w3.org/TR/rdf-sparql-query

identical meaning of concepts in different data sources on the web. It acts as the backbone of the semantic web vision [T. A. Powell, *(2003)* and W. W. W. Consortium et al., *(2002)*] which are considered as the next generation web. Moreover, an ontology contains core ontology, logical mapping, knowledge base, and lexicon. Furthermore, a core ontology, S, is defined as five tuples

$$S = (C, \leq_C, R, \sigma, \leq_R) \qquad [1]$$

Where C and R are two disjoint sets called "concepts" and "relations" respectively.

## 3. Present Structure

A mediator is a system that supports an integrated view [M. Di Giacomo, M. Martinez, and J. Scott, *(2004)*] over multiple information sources. The goal of a mediation system is to give a user the ability to issue a single query that would access multiple sources to retrieve different pieces of the result and would assemble these pieces to provide a composite response to the query. A major problem arises frequently when attempting to support information sharing among autonomous heterogeneous database systems is the occurrences of representational differences that exist among related data objects in different component systems. The heterogeneity problems [C. Och, R. King, and R. Osborne, *(2000)*] at the data level appear when the requester and the provider of a service use different databases to conceptualize their domain. The mediator component achieves this by relying on a set of mappings between the source and target database. Therefore, Mediator-based architecture is used to resolve geo-spatial semantic conflicts [Y. Bishr, *(1998)*]. The mediators are the pieces of software with embedded knowledge, for example, mediator consists of some reasoning system that has complex logical and mathematical functions for measuring semantic similarity. Mediator is also proposed as the principal means to resolve semantic conflict through an incremental domain approach that brings domains together when needed [M. S. Hossain and R. Mustafa, *(2007)*]. Experts build the mediators by putting their knowledge into them and keeping them up to date [G. Wiederhold, *(1998)*]. Moreover, it is difficult to develop an interoperable GIS for the Distributed data sources and Heterogeneity [M. R. Genesereth, A. M. Keller, and O. M. Duschka, *(1997)*].

Furthermore, a number of technologies have been developed for integrating several data sources. It provides frameworks for composing, reconfiguring, and reusing systems. Mediator languages, module interactions and database interaction facilities have been developed. The idea of using mediator architecture for integrating heterogeneous data sources is well established in the present age of technology. There exists many systems to solve geo-spatial semantic conflicts based on task hybrid and local schema based ontology DESMET, OBSERVER [Mena et al., *(2000)* and Mena et al., *(1996)*], DOME, COIN [Firat, et al., *(2002)*, Goh, et al., *(1999)*, Siegel, et al., *(1991)*] are task ontology based systems, SIMS [Ambite et al., *(1997)*, Arens et al., *(1993)*], Carnot and InfoSleuth [Carnot and Woelk., *(1993)*] are local ontology based systems, while KRAFT [Cui et al., *(2001)* and Cui. et al., *(2000)*] is hybrid ontology based system. Moreover, the TSIMISS [H. Garcia-Molina et al.,*(1997)*] and MIND [A. Dogac et al., *(1998)*] are also worked in the mediator field. TSIMISS integrates information in a common data model, Object Exchange model (OEM) [R. Goldman et al., *(1998)*], which can queried by application. MIND is a CORBA [T. J. Mowbray and R. Zahavi, *(1995)*] based multi-database system. The Fig. 1 gives us a close look of the general view of mediator based architecture.

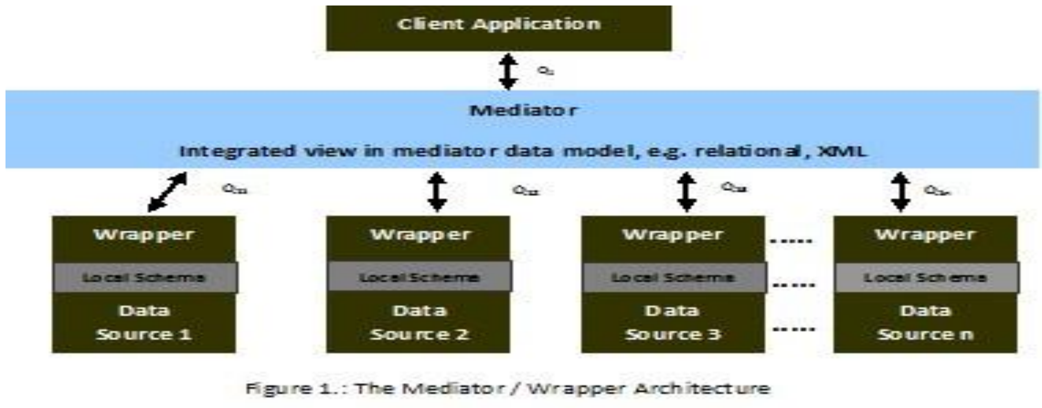


**Fig.1. General View of Mediator Based Architecture**

## 4. Semantic Architecture

The mediator based architecture is one of the most important that have been proposed to deal with the problem of integration of heterogeneous information. This architecture [B. F. Lo´ scio et al., *(2002)*] consists of three parts, one is for client request, intermediate is for mediator layer and the other is for data sources. In this work the data sources are registered with the mediator. Registering these data sources can possible to retrieve the heterogeneous data from the multiple data sources. Moreover, the structural heterogeneity is solved by performing the structural conversion on data. This involves field names and data types. The filter part of this module can filter the requesting query into a specific and meaningful way according to user requirements. All of the data at the sources and access on per need basis to retrieve and combine only the data that is relevant to a request. For that an intermediate software layer is introduced which presents a logically integrated view of the data sources to the users. This layer is a middle layer that separates the functions related to data integration from the data management functions of the data sources and the presentation functions of the applications. The goal of this layer is to simplify, abstract, merge and explain data. It consists of mediator module defined as Integration Mediation Kit (IMK).

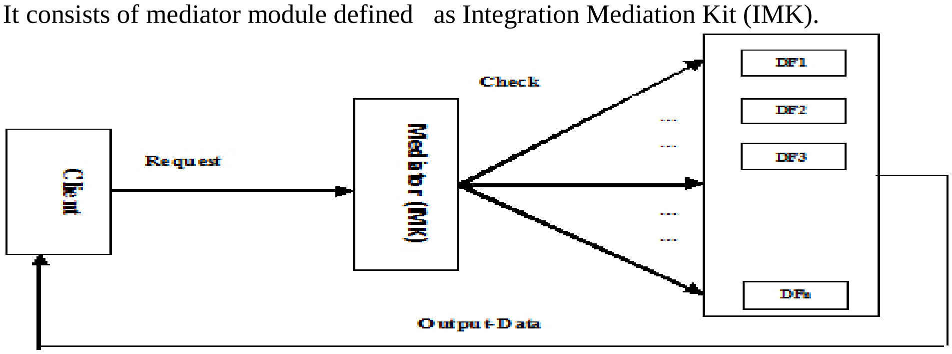


**Fig. 2. General View of Mediator Based Architecture**

The operation of this architecture is that the client request for a data (i.e. the authors publications against the authors name or authors id) then the requester sends this request to the mediator and the IMK is responsible for querying the data set, for this reason the IMK sends this query to other IMK in where the data resides. Finally all of these fragmented data are integrated into a common and responsive data set and sends as a return to the client. The Fig. 2 demonstrates the general view of a mediator system where the first part is the client in which all request are initialized, and then the requester sends these request to the mediator, and the mediator decides where the specific query result. Collecting the data from the data sources ensures the IMK and return the data set to the client.

Furthermore, Ontology defines common vocabularies for re- searchers [N. Noy, D. McGuinness et al., *(2001)*] who need to share information of a domain on the web of data. It is easier to publish data in RDF using available vocabularies from the web. In the case of unavailability of vocabularies, users can propose for a suitable vocabulary to describe domain data on the web. In order to identify these vocabularies we develop $Onto - pdb$ and $Onto - wasa$ ontology to describe our domain knowledge explicitly. The basic steps to develop an ontology is [41]: defining classes and arranging these classes in a taxonomic (subclass-super class) hierarchy, defining relationships with other classes called slots and allowed values for these slots. However, our knowledge data repositories $KB - pdb$ and $KB - wasa$ contains fundamental data related to these organizations taking into account classes, sub-classes, instances, relations, object property, data property and general axioms etc. It is important to select a vocabulary to maximize interoperability with wider consensus on the web. We use Dublin Core (DC) (dublincore.org/documents/dces/) and DCMI- BOX (http : //dublincore.org/documents/dcmi − box/) standard vocabularies to encode geographic meta-data of these domains. The Fig. 3 represents the approach of ontology integration of our application.

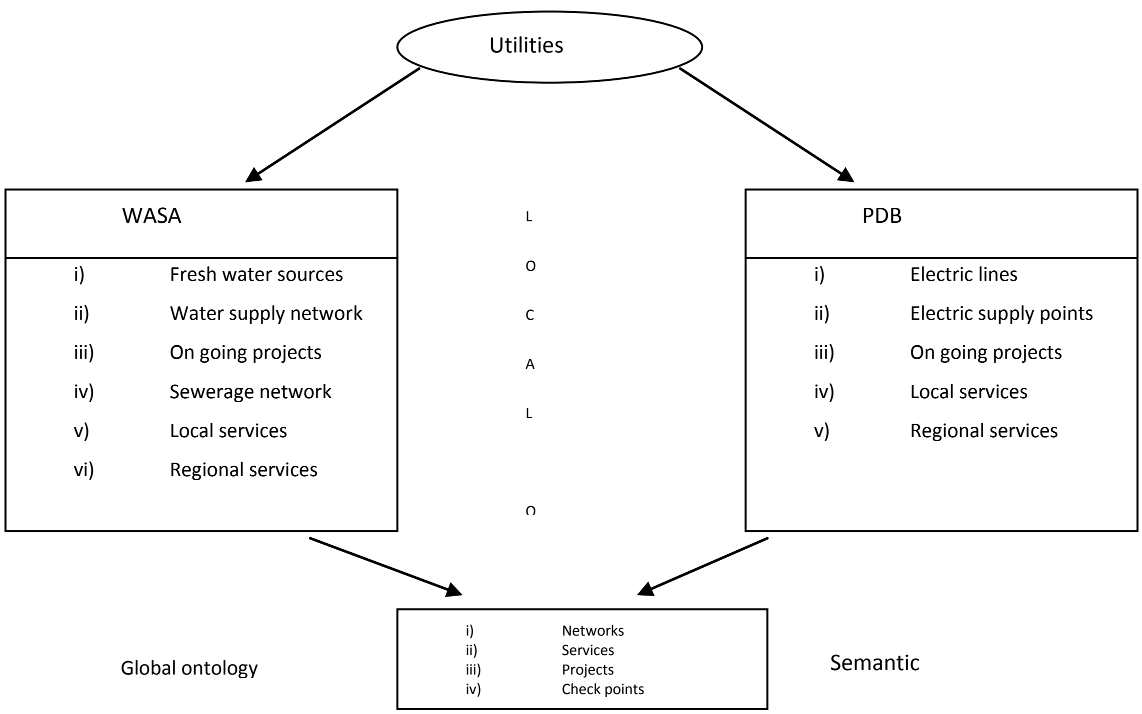


**Fig.3. Create local ontologies to global ontologies.**

## 5. Experiments and Evaluation

As described above, this mediator architecture encodes specific set of data and provides information for a higher level of applications. The information provided by the mediator is retrieved from underlying data sources. It is very easy situation that conflict arises so that it is solved by providing homogeneous interface to the clients. This architecture is an extension of the three layer mediator architecture introduced in [O. M. Group, *(1995)*] to four layer architecture that is used for the IMK mediator run time environment. The four functional layers of the run time environment of a mediator describes in the following steps: The application layer is the state where the client's data are stored; it is similar to all other application interface. The Data Integration layer is the collection of mediators which are responsible for the integration of data those are provided by the local data server layer. The Local Data Server responsible for storing the most commonly used data from the registering data sources and services provided by the local data source being integrated. The data source layer consists of the actual data sources such as vendor providing DBMSs raw files etc. Moreover, the IMK returns the information set from the heterogeneous data sources. For this architecture we choose the applicable domain in the multiple vendor providing data sources and the legacy file systems. Due to the different data sources involved, several numbers of heterogeneity arises. Based on the specific field it is possible for finding the complete result by searching all of these registered data sources. We use semantic search engine Sparql to retrieve more specific information from our knowledge base data repositories and maps to ease search ability by mass people. The Fig. 4 represents the integration view where we retrieve the Uniform Resource Identifier (URI) of each entity and retrieve related data from the chain of data web, and then integrated and locate in a map.

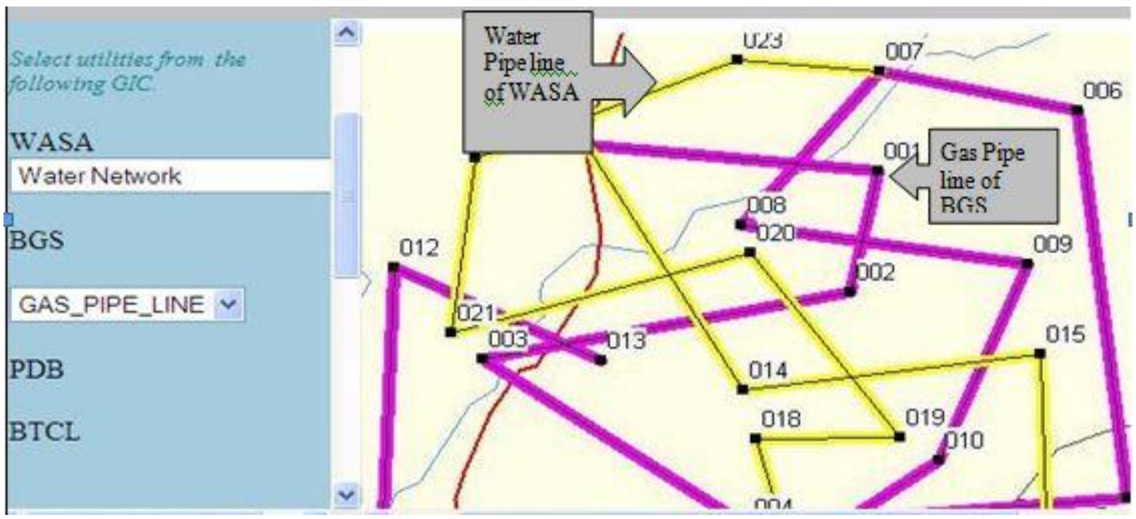


**Fig. 4. The integration view from two individual data sources**

## 6. Conclusion

For other consideration as an example, if there are two database servers, one of them is in the one server another is in the other server. The IMK helps us to get the full set of data by registering with the mediator system without establishing individual connection with the database server. This system resolves semantic conflict which in turns enables information sharing, information integration, interoperability and persistent interoperability in an efficient way. Moreover, this application supports other applications to use compatible data which decrease reproduction of these similar data on the web. Furthermore, it can help us to create a chain of data on the web that efficiently use web resources in terms of space. Therefore, our research represents data in a meaningful format which help us to retrieve specific information from the vast amount of repositories. Our research will map our locality of WASA and PDB to increase search ability of mass people by using mobile technologies.

## References

A. DOGAC, C. DENGI, AND M. T. O¨ SZU, (1998). Distributed object computing platforms, Communications of the ACM, vol. 41, no. 9, pp. 95–103.

AMBITE, J.L., ARENS, Y., ASHISH, N., KNOBLOCK, C. A. and collaborators (1997). The SIMS Manual 2.0. Technical Report, *University of Southern, California.* http://www.isi.edu/sims/papers/sims-manual.ps.

ARENS, Y., HSU, C. AND KNOBLOCK, C. A (1993). Retrieving and integrating data from multiple information sources. *International Journal in Intelligent and Cooperative Information System*s, Vol.2 (2), 127-158.

A. GERACI, F. KATKI, L. MCMONEGAL, B. MEYER, J. LANE, P. WILSON, J. RADATZ, M. YEE, H. PORTEOUS, AND F. SPRINGSTEEL, (1991). Ieee standard computer dictionary: Compilation of IEEE standard computer glossaries.

B. F. LO´ SCIO, A. C. SALGADO, AND V. M. P. VIDAL, (2002). Using agents for generation and maintenance of mediators, Journal *of the Brazilian Computer Society*, vol. 8, no. 1, pp. 32–42.

CUI, Z. AND O'BRIEN, P (2000) Domain Ontology Management Environment. *In Proceedings of the 33rd Hawai International Conference on System Science*s.

CUI, Z., JONES, D. AND O'BRIEN, P (2001). Issues in Ontology -based Information Integration. *IJCAI 200*1– Seattle, USA.

Carnot Project, http://www.mcc.com/projects/carnot

C. OCH, R. KING, AND R. OSBORNE, (2000). Integrating heterogeneous data sources using the coil mediator definition langauge, in *Proceedings of the 2000 ACM symposium on Applied computing*-Volume 2. ACM, pp. 991–1000.

C. H. GOH, S. E. MADNICK, AND M. D. SIEGEL, (1994). Context interchange: overcoming the challenges of large-scale interoperable database systems in a dynamic environment, in *Proceedings of the third international conference on Information and knowledge management.* ACM, pp. 337–346.

D. M. MARK, B. SMITH, AND B. TVERSKY, (*1999*). Ontology and geographic objects: An empirical study of cognitive categorization, *in Spatial Information Theory. Cognitive and Computational Foundations of Geographic Information Science. Springer*, pp. 283–298.

D. J. ABEL, B. C. OOI, K.-L. TAN, AND S. H. TAN, (1998). *Towards integrated geographical information processing, International Journal of Geo- graphical Information Science,* vol. 12, no. 4, pp. 353–371.

F. T. FONSECA, (2001). Ontology-driven geographic information systems, Ph.D. dissertation, State University of New York.

FIRAT, A., MADNICK, S. AND GROSOF, B (2002). Knowledge integration to overcome ontological heterogeneity: challenges from financial information systems. *Twenty-Third International Conferences on Information System*s.

GOH, C.H., BRESSAN, S., SIEGEL, M. AND MADNICK, S. E (1999). Context Interchange: New Features and Formalisms for the Intelligent Integration of Information. *ACM Transactions on Information System*s, Vol. 17(3), 270–293.

G. WIEDERHOLD, (1998). Weaving data into information, *Database Programming and Design*, vol. 11, no. 9.

H. GARCIA-MOLINA, Y. PAPAKONSTANTINOU, D. QUASS, A. RAJARAMAN, Y. SAGIV, J. ULLMAN, V. VASSALOS, AND J. WIDOM, (1997). The tsimmis approach to mediation: Data models and languages, *Journal of intelligent information systems,* vol. 8, no. 2, pp. 117–132.

J. G. BROOKSHEAR, *(2000). Computer science: an overview.*

J. F. SOWA ET AL., (2000). *Knowledge representation: logical, philosophical, and computational foundations.* MIT Press, vol. 13.

L. M. HAAS, E. T. LIN, AND M. A. ROTH, (2002). Data integration through database federation, *IBM Systems Journal*, vol. 41, no. 4, pp. 578–596.

M. DI GIACOMO, M. MARTINEZ, AND J. SCOTT, (2004). A large-scale digital library system to integrate heterogeneous data of distributed databases, in *Euro-Par 2004 Parallel Processing. Springer*, pp. 391–397.

M. S. HOSSAIN AND R. MUSTAFA, (2007). Resolving geo-spatial semantic conflicts–an interoperability issue, *Humanomics*, vol. 23, no. 2, pp. 102–109.

M. R. GENESERETH, A. M. KELLER, AND O. M. DUSCHKA, (1997). Infomaster: An information integration system, *in ACM SIGMOD Record*, vol. 26, no. 2. ACM, pp. 539–542.

MENA, E., KASHYAP, V., SHETH, A. AND ILLARRAMENDI, A (2000). Observer: An approach for query processing in global information systems based on interoperation across pre-existing ontologies. *Kluwer Academic Publisher*s, Boston. http://citeseer.nj.nec.com/mena96observer.html, 1-49.

MENA, E., KASHYAP, V., SHETH, A. AND ILLARRAMENDI, A (1996). Managing Multiple Information Sources through Ontologies: Relationship between Vocabulary Heterogeneity and Loss of Information. *In Proceedings of Knowledge Representation Meets Databases (KRDB'96*), ECAI'96 conference, Budapest, Hungary, 50-52.

M. SONDHEIM, K. GARDELS, AND K. BUEHLER, (1999). GIS interoperability, *Geographical Information Systems*, vol. 1, pp. 347–358, 1999.

N. NOY, D. MCGUINNESS ET AL., (2001). Ontology development 101: *A guide to creating your first ontology*.

O. M. Group, (1995). The Common Object Request Broker (CORBA): *Architecture and Specification. Object Management Group*.

P. R. VISSER, D. M. JONES, M. BEER, T. BENCH-CAPON, B. DIAZ, AND M. SHAVE, (1999). Resolving ontological heterogeneity in the kraft project, *in Database and Expert Systems Applications.* Springer, pp. 668–677.

R. M. SOLEY AND W. ANDREAS, (1992). *Object Management Architecture Guide: Revision 2.0.* Object Management Group, vol. 92.

R. J. MILLER, (1998). Using schematically heterogeneous structures, *in ACM SIGMOD Record,* vol. 27, no. 2. ACM, pp. 189–200.

R. LAURINI,(1998). Spatial multi-database topological continuity and indexing: a step towards seamless gis data interoperability, vol. 12, no. 4. Taylor & Francis, pp. 373–402.

R. GOLDMAN, S. CHAWATHE, A. CRESPO, AND J. MCHUGH, (1998). A standard textual interchange format for the object exchange model (oem).

R. STUDER, V. R. BENJAMINS, AND D. FENSEL, (1998). Knowledge engineering: principles and methods, Data & knowledge engineering, vol. 25, no. 1, pp. 161–197.

R. HOLOWCZAK AND W. LI, (1996). A survey on attribute correspondence and heterogeneity metadata representation, *in First IEEE Metadata Conference (IEEE, Silver Spring)*.

SIEGEL, M. AND MADNICK, S. E (1991). A metadata approach to resolving semantic conflicts. In Proceedings of the 17th Conference on Very Large Data Bases (Barcelona, Spain, Sept.). *VLDB Endowment 199*1, Berkeley, CA, 133–145.

S. J. RUSSELL, P. NORVIG, J. F. CANNY, J. M. MALIK, AND D. D. EDWARDS, (1995). *Artificial intelligence: a modern approach.* Prentice hall Englewood Cliffs, vol. 74.

T. A. POWELL, (2003). The complete reference html and xhtml.

T. BERNERS-LEE, J. HENDLER, O. LASSILA ET AL., (2001). *The semantic web, Scientific American,* vol. 284, no. 5, pp. 28–37.

T. BERNERS-LEE, M. FISCHETTI, AND T. DERTOUZOS, (1999). *Weaving the web: the original design and ultimate destiny of the World Wide Web by its inventor,* Harper Collins Publishers Inc.

T. J. MOWBRAY AND R. ZAHAVI, (1995). The essential CORBA: systems integration using distributed objects. John Wiley & Sons, Inc.

W. W. W. CONSORTIUM ET AL., (2008). Rdfa primer: Bridging the human and data webs, *Retrieved October*, vol. 4, p. 2009, 2008.

W. KIM, I. CHOI, S. GALA, AND M. SCHEEVEL, (1993). On resolving schematic heterogeneity in multi-database systems, *Distributed and Parallel Databases*, vol. 1, no. 3, pp. 251–279.

W. W. W. CONSORTIUM ET AL., (2002). Xhtml 1.0 the extensible hypertext markup language, URL: *http://www. w3. org/TR/xhtml1*.

Y. BISHR, (1998). Overcoming the semantic and other barriers to gis interoperability, *International Journal of Geographical Information Science,* vol. 12, no. 4, pp. 299–314.