Architecture of a Collaborative Business Intelligence Environment based on an Ontology Repository and Distributed Data Services

Valério Aymoré Martins, João Paulo C. Lustosa da Costa and Rafael Timóteo de Sousa Júnior
Department of Electrical Engineering, University of Brasília – UnB, Brasília, Brazil

Keywords: Collaborative Business Intelligence, Centralized Ontology, Data Services.

Abstract: Business Intelligence (BI) refers to a set of methodologies, methods, tools and software that are used in order to provide system solutions to support information analysis. The specifications and development of these system solutions are still limited to specific domain tables. Furthermore, in conventional BI solutions, it is necessary to promote massive data loads provided by other organizations in local repositories. Such massive loads can make the information not available on-time or cause errors due to misinterpreting received data. In this paper, we propose a systemic architecture that seeks solutions to these limitations. The architecture is based on a centralized ontology repository and uses distributed data services to provide data to generic analytical queries.

1 INTRODUCTION

While Business Intelligence environments in general are focused on semantic models about specific information domains and/or organizations, the Semantic Web seeks to organize public knowledge in a single semantic model that goes beyond these domain and organization boundaries.

In this context, the concept of BI 2.0 has emerged (Nelson, 2010) and brings a new perspective for its use on the Internet. The BI 2.0 combines the traditional BI together with features offered by Web 2.0 and supported by new Web technologies (Galatis and Tsekeridou, 2011).

This perspective is observed in Böhringer et al. (2010), which describes that, in the future, BI will support the use of: Collaboration to provide information (BI Crowdsourcing); Ontologies as a knowledge representation technique (Ontology-based BI); shared resources from decentralized BI systems (BI decentralization); and BI provided in cloud computing environments (Cloud BI).

To address these challenges, based on the concepts introduced by Berthold et al. (2010), we propose to establish a collaborative model composed of two integrated layers to handle BI environments. In Berthold at al., (2010), these layers are named Infospace (information space) and Dataspace (data space).

Inspired in this two layer model, in this paper we propose a Business Intelligence (BI) architecture that follows the paradigm of Dataspace and Infospace so as to improve the structure of conventional BI applications.

By employing Ontologies in our proposed architecture, a crowdsourcing ontology-based environment for Infospace can be created. At the same time, the use of Data Services can provide a decentralized Dataspace that can be supported by Cloud environments. With such environment, several partners and/or organizations can build information communities with minimum efforts.

To support the development of our proposed architecture, we describe the main features that can be selected and adapted from existing solutions in order to build an integrated environment. Then, we discuss our contribution, presenting the architectural model, its components and the related application integration process.

Finally, we discuss the application of our proposed ontology repository to integrate different BI systems. For instance, we can integrate the BI system of the Federal Patrimony Department (Fernandes et al., 2012) to BI systems of other departments and ministries in Brazil.

The remaining of this paper is organized as follow: in Section 2, we present an overview of BI concepts. In Section 3, it is shown the state of the art in the domains of business intelligence, ontologies

Aymoré Martins V., C. Lustosa da Costa J. and de Sousa Júnior R..
Architecture of a Collaborative Business Intelligence Environment based on an Ontology Repository and Distributed Data Services.
DOI: 10.5220/0004107000990106
In *Proceedings of the International Conference on Knowledge Management and Information Sharing* (KMIS-2012), pages 99-106
ISBN: 978-989-8565-31-0

and data services. In Section 4, we propose our architecture and its application. In Section 5 the conclusions are drawn.

2 BASIC CONCEPTS ON BUSINESS INTELLIGENCE

2.1 Structure of Traditional BI Environments

Existing BI solutions offer features that deliver results in different presentation styles and summarizations according to the user requirements. We highlight one of these features: the On-Line Analytical Processing (OLAP).

According to Chaudhuri and Dayal (1997), OLAP is a generic and convenient mechanism that allows data navigation through a multidimensional structure which performs information research and controls the way that information is presented.

To understand the use of OLAP, it is necessary to analyze the role of various elements existing within client-server architectures of a conventional BI environment. According to Davenport et al., (2007) and BI solution providers such as IBM (2004) and Microsoft (2006), there are five basic levels recognized in these architectures. These five levels are listed in Table 1.

Table 1: Layers of a conventional BI environment (Davenport et al., 2007); (IBM, 2004); (Microsoft, 2006).

#	Davenport	Microsoft/IBM	Primary Functions
1	**Data Management**	Data Sources	Management of data sources
2	**Transformation**	Data Integration	Extraction, clean and load (ETL).
3	**Repository**	Data Storage	Storage of data and metadata
4	**Application**	Data Analysis	Treatment of analytical data
5	**Presentation**	Data Presentation	Data manipulation and presentation

The first three layers in Table 1, related to the first three columns in Figure 1, **Data Management**, **Transformation** and **Repository**, are used in the construction cycle of conventional BI architectures. For instance, data from **Data Management** are used in a process called extraction, transformation and load (ETL) defined in **Transformation**.

The ETL loads the generated data and information into data models within the **Repository** layer. These data models are distinguished structures known as multidimensional models, implemented as physical or logical tables that hold both the aggregation of concepts and the metrics that link information and data.

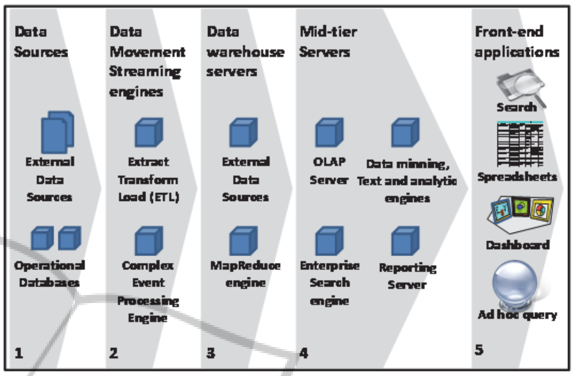

Figure 1: Conventional BI environment (Chaudhuri et al., 2011).

The fourth and fifth layers presented in Table 1, **Application** and **Presentation**, respectively the fourth and fifth columns of Figure 1, are executed during the usage cycle of conventional BI solutions.

Regarding the fourth and fifth columns in Figure 1, our particular interest is in the OLAP server in the role of middle-tier and the ad hoc query client that is the application front-end. Both are circled in Figure 1. These components cooperate via request and response protocols. In the usage cycle, the OLAP server directly accesses pre-defined multidimensional models, and the Repository layer reads data in order to build ad hoc information.

2.2 Multidimensional Models

The multidimensional modeling represents the main technique to meet the needs required in conventional BI environments.

Informational concepts are generally categorized using structured trees within multidimensional models. These trees organize the concepts from their genus, down to their species, a representation of a knowledge called taxonomy (Guarino, 1996). However, the taxonomy of concepts is an oversimplified representation with known limitations regarding the need to organize different levels of granularities from various information domains.

Regarding the process of representing informational concepts and how they relate to each other, modern literature explores another knowledge management model, known as ontology (Guarino, 1996); (Guarino and Giaretta, 1995); (Noy and

Musen, 2002); (Noy, 2010).

2.3 Ontologies and Ontological Representation

Ontology refers to the idea of set-of-concept-definitions, which is more general than taxonomy (Gruber, 2009). In such a set, the concepts are represented by classes, their attributes and their instances, linked by relations. According to Gruber (2009), they must be developed for the purpose of sharing knowledge between people and/or computational agents.

In this sense, ontologies can have a variety of formats (Jasper and Uschold, 1999) and have more components, allowing richer representations than the traditional taxonomy.

Moreover, the use of ontologies to represent concepts from different partners or organizations, if defined in conformance to a referential architecture, allows these concepts to be merged and expressed as a single semantic model, known as upper-level ontology, or just upper ontology.

2.4 Alignment and Merging Ontologies

According to Noy (2002, 2010), when two ontologies are developed based in a set of predefined rules, their automatic or semi-automatic alignment and fusion become possible, being implemented using resources of an existing system solution.

This process is accomplished with two activities: first, one must identify and align these ontologies based on their basic common components. Then, a merge process is executed to carry out a new upper ontology (Gruber, 2009); (Jasper and Uschold, 1999). Figure 2, from Abels at al., (2005), illustrates the alignment and fusion process. Figure 2(a) shows the identification and alignment of relations between two ontologies while Figure 2(b) sketches their merging and the resulting upper-level ontology.

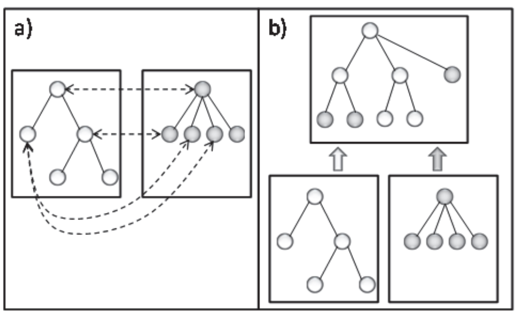

Figure 2: (a) Identifying and aligning the relationship and (b) merging between two ontologies (Abels, 2005).

The resulting model can be used in successive alignment and merge processes. This means that these processes may be continuously repeated by adding other ontological models and resulting in new upper ontologies.

However, during the generation of upper ontologies, inconsistencies can occur if the processes are done automatically. This can happen even when the ontologies have the same set of basic elements in their specifications (Noy and Musen, 2000).

3 STATE OF THE ART

In this section, we summarize the state of the art in the domains of ontological and data services environments, as well as BI solutions.

3.1 Ontological Environment

Given the merging process described above, and regarding the tools to build the ontological environment, we must consider two distinct needs: the construction of ontologies and the upper-level ontology generation.

For the ontological environment, the alignment processes and fusion are necessary in order to centralize the ontologies of the various partners. Such ontologies centralization environment ensures that similar concepts, such as same classes with overlapping instances or classified with different terms or with different levels of granularity, can be aligned even by inference of a human administrator.

Therefore, the merging process materializes an unique upper ontology and their correlated taxonomy in a multidimensional model, and so, it is possible to use an OLAP service with this unique model, in which the unrelated dimensions are treated.

For the construction of ontologies, there are well known tools, which key aspects are the ability to capture external ontologies and the edition of ontologies with standard representation languages. For the generation and record of an upper-level ontology there are ontology maintenance tools based on a centralized repository with options for aligning and merging (Noy and Musen, 2002).

As shown in Noy and Musen, 2002, and Abels et al., 2005, there are several studies about evaluation of tools for building, aligning and merging ontologies. Based on these studies, we point out advanced solutions such as COMA++, PROMPT and Glue. In particular, COMA++ provides advanced configuration of integration approaches and evaluation of similarities as well as the ability to implement new approaches.

3.2 Data Services Environment

The increasing use of distributed service-based data environments (Bennett et al., 2000) and the growth of the bandwidth in data transmission over the Internet (Kempf et al., 2010) favored the use of a data access mode based on decentralized and distributed data sources. However, since the integration is made between different partners with *a priori* unknown infrastructure environments, the use of interoperable standards and models are required.

Related to the techniques of Service-Oriented Architecture (SOA), there is an emerging standard technology to provide data on demand called Data as Services (DaaS), or just Data Services. These techniques use the extensible markup language – XML, as the basic exchange pattern (Hui et al., 2009).

Chaudhuri et al. (2011) states that the processes based on data services, which initially consisted of a simple storage of keys and values, have been enhanced to support the functionality of a single relational database in the form of a hosted service or a data provided service. This is the operation mode of Microsoft SQL Azure and Cloud Data Services in Amazon EC2.

Moreover, some organizations have developed protocols and services for managing and dynamically querying tabular data. This is provided by Google with GData, Microsoft with OData and Yahoo with DataRSS (Kansa and Bissell, 2010). Thus, these XML based standards are emerging associated with cloud computing initiatives.

However, since the XML traffic is yet extremely inefficient for any model, we suggest the incorporation of data cache mechanisms in BI environment for data services.

3.3 BI Solutions

In existing BI architectures, the main components responsible for the operations and support to answering queries accessing multidimensional data structures are the OLAP server and the analytical interface, as represented in Table 1, within the Application and Presentation layers, respectively.

Regarding the operationalization of our proposed architecture, the corresponding requirements can be fulfilled by adapting some existing open source platforms, including Pentaho BI, Spago BI and Palo BI (Liu and Lou, 2010).

We emphasize the use of solutions based on principles of Virtual Cubes, which allow an easy adaptation to higher models with unrelated dimensions.

Moreover, changes in the organization concepts of each BI system should be updated to the other BI systems. Finally, errors in a certain BI system can be propagated to the others reducing the reliability of the integrated system in Figure 3.

In Figure 3, we exemplify traditional solution for integrating four BI systems of different organizations. Each BI system should allow exchanging information beyond its domain.

4 PROPOSED ARCHITECTURE

In our proposed architecture, we consider the ontological and the data services environments as solutions to establish the Infospace and Dataspace, respectively. In practice, these environments are integrated using common components of BI platforms.

4.1 General Structure of the Proposed Architecture

In Figure 4, we identify and place the components along with the general structure of our proposed architecture.

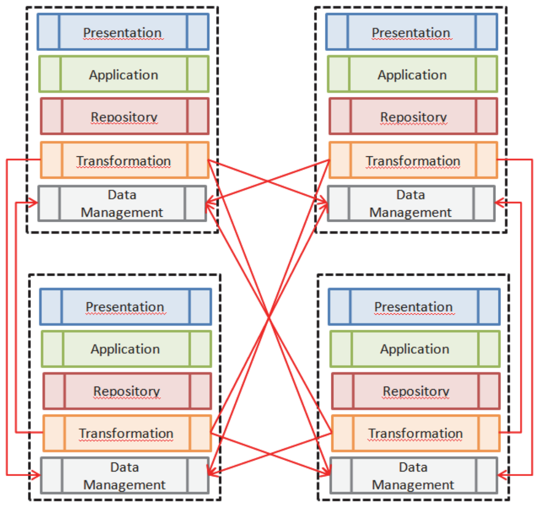

Figure 3: Example of traditional integration of four BI systems.

According to Figure 4, we distinguish three environments: **User environment**, **Collaborative BI environment** and **Organizational environment**.

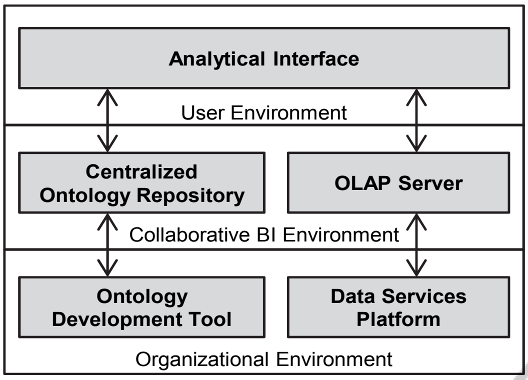

Figure 4: General structure of the proposed architecture.

The **User environment,** represented by the front-end web application, is used to make information queries. This environment is associated with the Presentation layer in Table 1.

The **Collaborative BI environment** is the core service provider in our proposed solution. This environment is associated with the Application layer in Table 1.

The **Organizational Environment** is represented by ontological development tools and Data Services that are provided by each of the partners and thus are located within the partners environments. This way, differently from the conventional BI architecture, which directly accesses the local Repository, in our proposal data and information are remotely accessed by means of Data Services.

It is worth to note that the Data Management and Transformation layers in Table 1 are not included in the scope of this work, since they are placed within the partner or organization boundary. Thus, each partner or organization is responsible for its own data quality management and interpretation.

Also in Figure 4, each layer may have one or more components. For instance, the **User environment** has only one component which is the **analytical interface platform** existing in BI platforms. In our architecture, this component needs to be adapted to read the ontological model placed in the centralized repository.

In the **Collaborative BI environment**, there are two components: the centralized ontology repository and the OLAP Server.

The **centralized ontology repository,** integrated with a correlated ontology development tool, provides and integrates concepts using resources for the alignment and merging of various ontologies. This repository must support the management of semi-automated ontology merge processes.

The **OLAP server** solution accesses the remote data services as data sources. This server needs to interact with the contents placed in the ontology repository to generate multidimensional models at runtime.

In the **Organizational environment** we have the other two components: the ontology development tool and the data services platform.

The **ontology development tool** creates and updates the conceptual model of the information created by the partners. This tool is based on techniques and standards that enable successive ontology alignment and merge steps, in order to compose the upper-level ontology.

The **data services platform** enables the collaborative BI environment to access the partner organization environments in compliance to specified standards of SOA Data as a Service.

In order to show the feasibility of our proposed architecture, we show its constituents in Figure 4 and describe them hereafter.

4.2 Layers and Cycles of the Proposed Architecture

Similarly to a conventional BI environment, we also divide our proposed architecture into layers. However, we consider only four layers, which are named: Interface layer, OLAP layer, Ontology layer and Data Service layer.

The **Interface layer** uses the upper ontology recorded in the centralized ontology repository to ensure the formation of a consistent model. The centralized ontology repository stores the relationships between classes, instance and metrics, as well between metrics and their sources. The major concern found in this layer is to keep control given the constraints imposed by these relationships.

The **OLAP layer** receives the request and constructs the response in multidimensional cubes. There are no major concerns about the integrity between the hierarchies and the selected metrics because these are ensured previously by the Interface layer. Thus, differently from reading a pre-defined multidimensional model, this layer allows the dynamic construction of a sufficient and necessary multidimensional model from the centralized ontology repository.

The **Ontology layer** is materialized both within the limits of organizations playing a client role as well as within the Collaborative BI Environment acting as a server. This way our proposed architecture provides elements that can be combined within different approaches for the integration of heterogeneous ontologies.

The **Data Service layer** is used to publish and provide data as a service. Therefore, the goal of this layer consists of decoupling the partner's concepts from the sources of data. It is worth to note that this layer applies two SOA design patterns, namely the Service Loose Coupling and Service Abstraction.

Now regarding the development of applications based on the proposed architecture the process, similarly to that of a conventional BI environment, must be performed in two cycles, named **Construction** and **Usage cycle** as represented in the second and third columns in Figure 5.

The **Construction cycle** involves tools for building and integrating conceptual models within the centralized ontology repository and providing the related access to data services published by each partner using its Data Service Platform.

In the **Usage cycle**, on behalf of the BI user the analytical interface interacts with the OLAP server. The OLAP server requests data as service from the necessary partners and then generates and delivers the multidimensional response back to the analytical interface.

In Subsection 4.3, we present a description of the basic process and elements involved in each of these cycles.

4.3 Processes and Elements Involved in the Construction Cycle

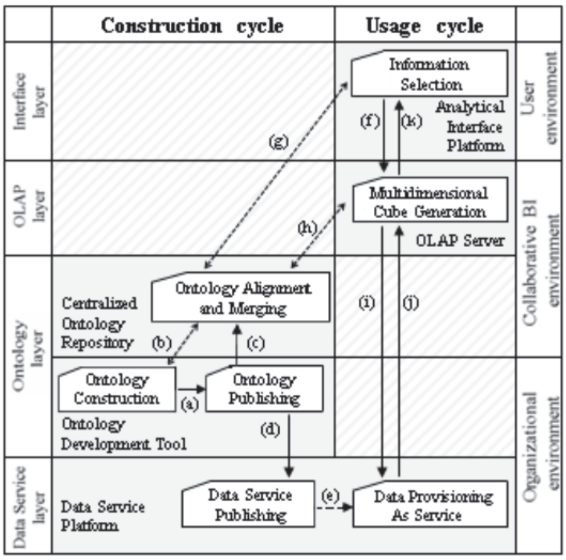

Figure 5: Environments, cycles, layers, and processes of the proposed Collaborative BI architecture.

Using the **ontology development tool**, a new partner performs an ontology construction resulting in the conceptual model of information **(a)**. This process can perform an initial capture of an existing ontology from the **centralized ontology repository**, and then use it as basis for the client solution **(b)**.

Also using the **ontology development tool** linked to the **centralized ontology repository**, the partner performs the **ontology publishing**, i.e. executes a handshake process until the model is accepted **(c)**. After that, an underlying application generates the proposals of Data Services **(d)**.

Next, this new partner performs a Data Service publishing, i.e., turns these data services available in its service inventory **(e)**.

At the end of this publishing task, an additional underlying application can be used to evaluate the queries to the Data Service in order to ensure the overall model performance.

4.4 Processes and Elements Involved in the Usage Cycle

By using the **analytical interface platform**, the end-user performs the **information selection** process, i.e., the user selects and filters concepts and metrics, as well as he adjusts the output of columns and rows to fulfill the business requirements **(f)**. The use of this interface is controlled by the upper-level ontology structure loaded from the **centralized ontology repository (g)**.

These user selections are sent to the **OLAP server** as data requirements. The OLAP server reads the multidimensional structure from the upper-level ontology at the **centralized ontology repository** as needed **(h)**.

Then, the **OLAP server** prepares and directs the necessary data requests to **data provisioning services** provided by the **data service platforms** of the involved partners **(i)**. When all data are returned, the OLAP server executes the **multidimensional cube generation (j)** and routes the result to the **analytical interface platform (k)**.

4.5 Applications of the Proposed Architecture

With our proposed architecture, strategic information networks can link concepts and data from various partners. This integration can be better reached if the data service layer of each involved partner is conformant to a BI architecture. Moreover, the fitting and use of systemic elements already existing simplifies the construction of the intended environment.

By applying semantics in conjunction with business intelligence assessments, we can relate to various subjects such as in the areas of public policy, security, economy, education. (Ludwig, 2005)

In Figure 6, we present our proposed centralized ontology repository, which adjusts its ontology according to taxonomy of the four BIs that are integrated. Moreover, in case of inconsistency of a certain BI system, the centralized ontology repository may ignore it and consider only the remaining BI systems.

Additional tasks may be performed by the administrator in order to create pre-defined indicators for general use inside the centralized ontology repository. These tasks fulfill the requirements proposed by Berthold et al. (2010).

Although our architecture can be easily built, some questions related to performance are identified. In this sense, we point out some future improvements to solve these questions: the use of optimized mechanisms of SOA transport, the implementation of cache schemas in OLAP servers and data services, the setting of restrictions on the amount of data that can be generated, the implementation of compression techniques to transfer data from the Data Service layer to the OLAP layer.

Another crucial aspect is the capacity to fully automate tasks in the aligning and merging processes. The commitment to fully implement the automation in a sole step seems to be unreasonable, since this process requires information exchanges regarding similarities, an activity that still imposes human intervention. Therefore, it is required a mediator to check if a minimum consistency level has been reached, otherwise an automated solution may affect existing models of the participants.

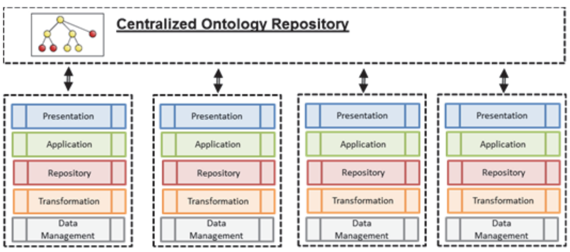

Figure 6: Example of the proposed centralized ontology repository for integrating four BI systems.

However, this effort can be minimized if the selected elements for the ontology layer are able to use a rich combination of different approaches for ontology integration, such as measuring the similarity between texts, extraction of text keywords, execution of language-based analytical methods, identification of relationships between words, evaluation of similarity between types of data with assessments in domains and value ranges, general structural and taxonomic analysis, integration of data with analysis of key properties, and graphical mapping.

5 CONCLUSIONS

In this paper we propose a collaborative BI environment architecture in which the composition and treatment of analytical queries are based on the interoperation of a centralized repository of concepts and decentralized data services.

Our approach departs from a conventional BI environment in several respects, but mainly its two founding principles. First, our proposal is based upon the integration of heterogeneous semantic concepts so as to compose upper ontologies. In addition, source data retrieval is accomplished according to fundamental SOA practices, such as low coupling and abstraction.

This way, our architecture constitutes an improved alternative to the conventional BI structure, offering a distributed solution that is able to integrate heterogeneous information concepts.

Finally, as a future work, we propose to integrate BI systems of the Brazilian government based on the Centralized Ontology Repository in Figure 6.

REFERENCES

Abels, S., Haak, L., Hahn, A., (2005). Identification of Common Methods Used for Ontology Integration Tasks. *University of Oldenburg - Business Information Systems*- Oldenburg, Germany.

Bennett, K., Layzell, P., Budgen, D., Brereton, P., Macaulay, L., Munro, M., (2000). Service-based software: the future for flexible software. *Asia-Pacific Software Engineering Conference*, vol. 0, p. 214.

Berthold, H., Rösch, P., Zöller, S., Wortmann, F., Carenini, A., Campbell, S., Bisson, P., Strohmaier, F., (2010). An Architecture for Ad hoc and Collaborative Business Intelligence. *ACM International Conference Proceeding Series*, ACM.

Böhringer, M., Gluchowski, P., Kurze, V., Schieder, C., (2010). A Business Intelligence Perspective on the Future Internet. *Americas Conference on Information Systems, AMCIS 2010 Proceedings*, Paper 267.

Chaudhuri, S., Dayal, U., (1997) An overview of data warehousing and OLAP technology, *ACM SIGMOD Record*, vol.26, no.1, pp.65-74, March 1997, doi: 10.1145/248603.248616.

Chaudhuri, S., Dayal, U., Narasayya, V., (2011) An overview of business intelligence technology.

Common, *ACM* 54, August 2011, 88-98. DOI=10.1145/1978542.1978562.

Davenport, T. H., Harris, J. G., (2007) *Competing on Analytics: The New Science of Winning*. Harvard Business School Press, 2007, pp 240.

Fernandes, A. A., Amaro, L. C., da Costa, J. P. C. L., Martins, V. A., Serrano, A. M. R., de Sousa Jr., R. T., (2012) Construction of Ontologies by using Concept Maps: a Study Case of Business Intelligence for the Federal Property Department. *International Conference on Business Intelligence and Financial Engineering (BIFE'12)*, Lanzhou & Tunhuang, China.

Galatis, G., Tsekeridou, S., (2011) Business Intelligence On 2.0 Era: A Framework Described With Emphasis On Opinion Mining, *Thesis submitted for Master Of Science. Management of Business, Innovation & Technology (MBIT)*, Athens, Unpublished.

Gruber, T., (2009) What is an Ontology?. *Encyclopedia of Database Systems*, Ling Liu and M. Tamer Özsu (Eds.), Springer-Verlag, 2009.

Guarino, N. (1996) Understanding, building and using ontologies. In: *Proceedings of Knowledge Acquisition for knowledge-based systems workshop. Knowledge Acquisition Workshop - KAW'96*, Banff, Alberta, Canada.

Guarino, N., Giaretta, P., (1995) Ontologies and Knowledge Bases: Towards a Terminological Clarification. In N. Mars (ed.) *Towards Very Large Knowledge Bases: Knowledge Building and Knowledge Sharing* 1995. IOS Press, Amsterdam: 25-32.

Hui, M., Jiang, D., Li, G., Zhou, Y., (2009) Supporting database applications as a service. In: *ICDE '09: Proceedings of the 2009 IEEE International Conference on Data Engineering,* pages 832-843. *IEEE Computer Society.*

IBM, (2004) Introduction to BI Architecture Framework and Methods. *IBM Group. DB2 Data Management Software*. IBM Corporation.

Jasper, R., Uschold, M., (1999). A framework for understanding and classifying ontology applications. *IJCAI-99, Ontology Workshop*, Stockholm, S. 1. : s. n.

Kansa, E. C., Bissell, A., (2010). Web Syndication Approaches For Sharing Primary Data in Small Science Domains. *School of Information, Data Science Journal*, Volume 9, 8 July 2010.

Kempf, J., Nikander, P., Green, H., (2010*). Innovation and the Next Generation Internet. INFOCOM IEEE Conference on Computer Communications Workshop*, March 2010, pp.1-6, 15-19, doi: 10.1109/INFCOMW.2010.5466657.

Liu, X., Lou, X., (2010). A Data Warehouse Solution For E-Government. *International Journal of Research and Reviews in Applied Sciences - IJRRAS*, vol.4, issue 1. July 2010.

Ludwig, L., (2005). *Business Intelligence und das Semantic Web: ein Traumpaar*. Retrieved June 04, 2009 from http://www.competence-site.de/business-intelligencehr/Business-Intelligence-und-das-Semantic-Web-39683.

Microsoft, (2006). Business Intelligence Guidelines Conceptual Framework. *Microsoft Corporation*.

Nelson, G. S., (2010). Business Intelligence 2.0: Are we there yet?, *SAS Global Forum Business Intelligence/Analytics*, Paper 040-2010.

Noy, N., Musen, M. A., (2000). Algorithm and Tool for Automated Ontology Merging and Alignment. From: *AAAI-00 Proceedings. AAAI* (www.aaai.org).

Noy, N., Musen, M. A., (2002). Evaluating Ontology-Mapping Tools: Requirements and Experience. *Workshop on Evaluation of Ontology Tools at EKAW'02 (EON2002)*. 2002.

Noy, N., (2010). Ontology Mapping and Alignment. *Fifth International Workshop on Ontology Matching collocated with the 9th International Semantic Web Conference ISWC-2010*, Shangai, China.