Designing a General Architecture for Data Interchange

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Abstract: The paper describes principles for designing a general framework for automatic data interchange that scopes all three levels, data, semantic and knowledge. In spite of the huge amount of research already performed and existing standards and products, there is room to enhance information and knowledge integration. Consequent to defining the data interchange framework, we are going to apply these principles in developing and implementing a solution for academic data interchange. Such a solution has the potentiality for important advantages in academic cooperation and societal benefits.

1 INTRODUCTION AND WORKING FRAMEWORK

Interoperability is the capability of different systems to share functionalities or data (Olmedilla et al, 2006). System interoperability has been dealt with by means of various models (Morris et al, 2004) and has been extensively researched for business processes (Ziemann, 2010).

Interoperability may be achieved by: *system integration* (Chapman, Kihn, 2009), which has also been mainly tackled in the literature for business and organizational processes (Hasselbring, 2000), (Hasselbring, Pedersen, 2005), a *semantic approach*, or *data exchanges*, with important results for business processes. Interoperability issues have to be considered on a three layer basis.

1. A first layer concerns *data interoperability*. For this, several standards have been developed, like XML and SQL standards. They also solve syntactic interoperability issues. In the last decade, many instruments have been developed, mainly driven by the necessity of solving Business-to-Business and e-commerce problems. For instance, ebXML (OASIS, 2007) has been developed as a new, global standard for Internet-based B2B e-commerce (Gibb, Damodaran, 2002). Also, several specifications have been developed, like AS2 for secure and reliable transport of data over the Internet, AS4 (AS4 web, 2012) for B2B documents exchange using Web services, using XML encryption and XML Digital Signature, or ebMS, a communication mechanism which has to be implemented for business document exchange within the ebXML standard.

The Electronic Data Interchange (EDI) model (Adams et al, 2002) was proposed for standardizing business information exchange, various formats being used in this respect: ANSI X.12, XML (cXML, xCBL, OpenTrans, UBL).

XML (eXtended Markup Language) (XML web, 2010) is a widely used standard for information structuring and information exchange. XML is often used as a format for data exchange and integration between web applications or services within organizations, and accordingly, integration of XML data has become an important research problem. Studies regarding the XML definitions dedicated to representing database structures already lead to a XML representation of a database and algorithms for obtaining it (Abiteboul et al, 2000), (Bourret, 2000).

Analytical processing of data distributed in the World Wide Web is an important topic for current research (Heflin, Stuckenschmidt 2012). XML data integration (Le et al, 2006), (Algergawy et al, 2010) or RDF-based integration (Karnstedt et al, 2012) involves reconciliation at different levels: (1) at schema level, reconciling different representations of the same entity or property, and (2) at instance level, determining if different objects coming from different sources represent the same real-world entity. An important problem to be solved for XML-based data integration is the support for integrated access to the data using advanced query processing capabilities (Manolescu et al., 2001), (Sattler et al,

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2005). The unique correspondence between the database schema and its XML representation is tackled and proved in (Andreica et. al, 2005). Current approaches for analytical processing on integrated (Algergawy et al, 2011), (Heise, Naumann, 2011) or distributed (Vouros et al, 2010) data, sometimes based on cloud or grid architectures, give good frameworks for application development.

The learning objects model LOM and the SCORM standard (SCORM web, 2012) have been improved in various directions: personalized adaptive learning frameworks based on user profiles (Arroyo et al, 2006); *activating learning objects* with DBLink (Kassahun et al, 2006); describing how learning objects should be used within VC-LOM (Virtual Campus-LOM) (Di Nitto et al, 2006); universal interoperability layer for educational networks with Simple Query Interface (SQI).

Currently, various learning standards (Walker, 2012) are being used: standards for moving content (IMS Common Cartridge (CC-MS web, 2012), SCORM 2004's Content Management Component), data standards, like SIF Association www.sifinfo.org - and PESC (PESC-CEDS web, 2012), integration standards - PESC's Data Transport Standard, SIF (SIF Specifications web, 2012), IMS Learning Tool Interoperability (LTI-IMS web, 2012), AICC-CMI (AICC web, 2012) and some of them creating interoperability contexts, such as SCORM, DCMI, PESC or Ed-Fi. The Systems Interoperability Framework (SIF) Association has achieved relevant results, proposing specifications for event reporting, data provisioning, messages and agents.

Among messaging standards, we enumerate: RosettaNet (Rosetta web, 2011), ebMS (ebXML Messaging Service) (OASIS, 2007), AS2 (Applicability Statement 2) (AS2 web, 2012).

2. The second layer is the *semantic layer*. Semantic interoperability is the ability to share the meaning of electronic documents using computer systems. Knowledge discovery, inference, logic are enabled by semantic interoperability. Semantic interoperability is mainly achieved using ontologies (Dicheva et al, 2005), (Yuan et al, 2010).

The Resource Description Framework (RDF) (Lassila, Swick, 1999), a data model of metadata instances, is recommended by the W3C (World Wide Web Consortium) in order to solve semantic interoperability problems. SHOE (Simple HTML Ontology Extensions) (Heflin, Hendler, 2000) introduces an ontology-based knowledge representation language designed for the Web that supports interoperability by sharing and reusing ontologies. The Open Group (Open web, 2012) focuses on developing a particular open standard to facilitate semantic interoperability: the Universal Data Element Framework – UDEF (UDEF web, 2012). UDEF framework is integrated with the Resource Description Framework (RDF) and especially used for describing business operations.

3. The third layer is the *knowledge layer* and it addresses the conceptual structure of the shared data, information and knowledge. Knowledge sharing over computer information systems is a major task for the interoperability approach. The first step is to identify and automatically discover knowledge. This process is based on a common cultural and social background, enabling the user to identify and use the extracted knowledge. Technically, the process uses the previous two layers, and is based on the Conceptual Knowledge Processing paradigm (Stumme, Wille 2000). Transparency about the identified knowledge has to be ensured. Active knowledge systems enable to capture and represent knowledge, as well as to reason and to draw appropriate conclusions (Hitzler, Schärfe, 2009).

We consider that the Open Internet of Things standards (OpenIoT, 2013) may be used as an efficient framework for data interchange.

2 DATA INTERCHANGE PRINCIPLES

We aim at proposing a general data interchange model as a data interchange and interaction model, valid for various fields. The framework we design is based on the principles described below.

We use standards for the agent based system development, and for the communication between the agents within the multi-agent system, in the form of FIPA-ACL (FIPA web) messages.

We adapt agent-oriented methodologies - like Gaia (Wooldridge et al, 2000) - for MAS development influence interoperability within the system. Ontologies (Gruber, 1993) are used for achieving semantic interoperability in the multi-agent educational system. Ontologies are powerful tools for sharing knowledge sources in a scalable, adaptable and extensible manner and as well for reaching semantic interoperability among heterogeneous, distributed systems.

We use a multi-agent architecture (Weiss, 1999) for designing the data exchange model proposal in order to benefit from the advantages that agent based technology offers: decentralization, extensibility, robustness, maintainability, flexibility. In order to preserve confidentiality of the interchanged data, as well as for security reasons, the mobile agent (Nwana, 1996) technology is used. We provide self-adapting communicating objects, which work on distributed datasets not only supporting the exchange but also the analysis of distributed sources.

The knowledge layer is based on the Conceptual Knowledge Processing paradigm, which makes use of concept lattices, i.e., knowledge maps displaying concepts and their hierarchies, with a clear semantic and a very high expressivity. The methods used in this respect are knowledge discovery, knowledge acquisition, knowledge development, knowledge distribution and knowledge sharing. They are based on Formal Concept Analysis (Ganter et al, 2005), the mathematical theory of concepts and their hierarchies, which is a widely accepted standard of knowledge processing and representation.

We use the Open Internet of Things standards (OpenIoT, 2013) as a framework for data interchange; the “Utility/Application Plane” and “Virtualized Plane” (OpenIoT, 2013) layers provide a flexible framework for information communication and exchange, including cases of cloud hosted data.

3 ACADEMIC APPLICATION CASE

A specific application case of the data interchange model we are developing is the academic field. In this respect, *system inter-operability* capabilities, based on data interchange techniques, provide support for student or teacher mobility and e-learning content exchange, relevant for networks of universities with common programs. We note that e-learning content exchanges are important mainly in partner educational networks.

We take into account specific academic information, such as study levels, specializations, courses, students, teachers, grades, as well as e-learning content resources. This information standardisation has important benefits for exchanging information in various systems, including cloud services. Efficient data interchange components increase academic activity proficiency, with important societal benefits.

The proposed model for academic information exchange –fig. 1, supports semantic interoperability. This framework may also be used for advanced data analysis. We propose a Reference Interaction Model for defining the data content that is needed to provide an explicit representation of semantic and lexical connections that exist between academic entities and we implement intelligent agents. The interaction framework among the functional components of the academic information system environment is built using actors and transactions.

We define Integration Profiles for sharing information within academic institutions and across networks. Integration Profiles address data analysis and interoperability issues related to information access for academic actors and students, academic workflow, security and administration infrastructure, as well as for potential community or business actors. Each profile defines the actors, transactions and information content required to fulfil common interactions between academic entities or services provided to community stakeholders.

Multi-agent systems (MAS) are appropriate for modelling the academic domain, which involves interactions between various organizations with different (possibly opposite) goals (Shen, Barthes, 2001), where flexible autonomous actions are required for achieving the goals. Ontologies and agent technologies may be combined in order to successfully enable heterogeneous knowledge sharing. We develop components for exploring and reasoning on large-scale educational data to better understand learners' educational evolution, assess their progress and evaluate learning environments.

We use abstract methods for agents’ database access (Han, Kamber, 2006), and particularize them for certain standard academic information system technologies. We exploit the advantages of using intelligent agents as a support for the active data mining (Agrawal, Psaila, 1995). For example, when new data is added, a triggering agent can notify the main mining application, so that new data can be compared to the already mined data. Another scenario regards sending alerts and notifications in critical situations (i.e., possible frauds).

Data mining (Han, Kamber, 2006) and knowledge discovery techniques are used to find interesting relationships and patterns within academic data (e.g. attributes of students, assessments). Machine learning techniques, such as reinforcement learning (Sutton, Barto, 1998), are useful for learning teaching strategies in an adaptive and intelligent educational system. Intelligent triggering software agents are efficient for sending alerts in critical situations (i.e., frauds, etc.).

We are implementing distributed data mining techniques (Domenico, Trunfio, 2010) (e.g. fraud detection, students’ profiling) within the educational system. The agent based model is used within the distributed data mining architecture, the mobile

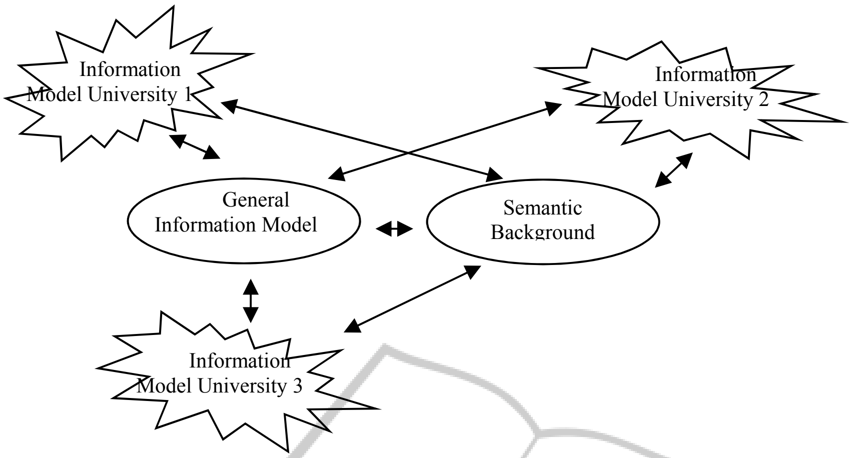

Figure 1: Heterogeneous sources, General Information Model and Semantic Background Knowledge.

agent model being useful for preserving academic data confidentiality.

Machine learning techniques (Mitchell, 1997) are used in order to enrich the educational system with the characteristics of intelligence and adaptability. We develop and use computational intelligence and machine learning techniques (e.g. learning and teaching, intelligent tutoring, adaptive information filtering, etc): *relational association rules mining* (Şerban et al, 2008) for predictive modelling (e.g predicting the most appropriate specialization for a student, predicting the students' grades, etc); *fuzzy* to deal with imprecision, uncertainty, partial truth; *unsupervised classification techniques*, such as clustering (Jain, 2010) and self-organizing maps (Kohonen et al, 2001) in order to uncover hidden patterns within academic data (students' profiling,identifying groups of students sharing common interests, etc); reinforcement learning techniques (Sutton, Barto, 1998) in order to discover users' (students, teachers, etc.) preferences, to recommend specific tasks to students, according to their preferences, to develop optimal teaching strategies by adapting tutoring to students' needs; *approaches that ensure privacy* - e.g. (Tran, Küng, Quoc 2011) proposes a particular k-anonymity technique that does not affect the association rule mining quality.

We are developing intelligent techniques for data cleaning within academic data collections, using techniques that detect and correct data errors. Data cleaning is an important pre-processing step in a data mining process; various computational intelligence techniques such as relational association rules (Şerban et al, 2008) are used in this respect.

Existing SIF (SIF Specifications web) standards are adapted for performing the exchange, management and integration of electronic academic information. It is important to develop means and specifications that ensure messaging standards for academic transactions in order to achieve interoperability. Such standards increase the effectiveness and efficiency of academic information delivery within and among academic organizations.

4 CONCLUSIONS

We describe the principles we are applying in designing a general framework for data interchange between information systems. The general data interchange model is extremely useful for ensuring entity cooperation in various fields. The model will be applied for the academic field.

The data interchange model we design is going to provide: *advanced data exchange services* using self-adaptive software communicating objects which provide academic IT services within distributed architectures; *a standardization framework* which supports information management and data exchange, ensuring interoperability in software technologies and services; *a* platform independent *software solution for academic data exchange*, with important social and collaborative advantages – as a flexible software tool for sustaining academic communication and cooperation. The solution meets all privacy requirements of academic institutions and national laws.

The application case for the academic field will provide important advantages for increasing academic competitiveness, with a significant societal impact on academic institutional cooperation, student and teacher exchanges, efficient information management and access to data analysis facilities for academic and community stakeholders. A relevant advantage of the solution is its flexibility and efficiency, including real-time response features, efficient information exchange (only relevant data is exchanged), with minimal resources involved.

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