Shifting the construction interoperability paradigm, in the advent of Service Oriented and Model Driven Architectures

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ABSTRACT: A major difficulty construction companies are currently facing is the lack of interoperability of software applications to manage and progress in their business. Organizations are being pressured up by new business relationships, driven for instance by new contractual challenges, which the exchange of information and documents with new partners are often incapable of being executed automatically and in electronic format. This is principally due to problems of incompatibility with the information representation adopted by the software applications they are working with. This problem arises not only during the project phase but also across the whole life cycle that includes operation and maintenance stages. In order to create the enabling conditions for the deployment of the electronic collaborative and commerce platforms it is fundamental to understand the variables that may influence its development, and how they determine the configuration of the e-platform. This paper, after present technology driven standards for the construction industry data management, it proposes the adoption of the emerging Service Oriented and Model Driven Architectures to shift forward the interoperability paradigm in this industrial sector. The paper illustrates some scenarios where significant impact is expected when adopting the proposed methodology.

1 TECHNOLOGY DRIVEN STANDARDS

During the past decade the need for innovation and standardization has been recognized by several sectors. For instance, in the United Kingdom the government set up a Construction Best Practice Programme (CBPP) and an industry–led Movement for Innovation (M4I) [8]. The Japanese Ministry of Construction has established an action program (SCADEC) whose main objective is to develop a neutral CAD data exchange format based on STEP AP202 [23].

The major results from the projects previously presented pointed out that the adoption of normalized methodologies and platforms to achieve an adequate level of integration of applications and interoperable open environments would be indispensable. Primarily, the development and adoption of standard models for representation of the data structures was identified as the key to sustain the core of the integrated systems.

In an effort to provide an answer to these requirements, the TC184/SC4 (Industrial automation systems and integration - Product data representation and exchange: Industrial Data) of the International Organization for Standardization (ISO) launched, within its WG3 (Product Modeling), the T22: Building Construction Group. Under the umbrella of T22, for ISO10303-STEP, the part 225 titled: "Application Protocol (AP): Building Elements Using Explicit Shape Representation" was developed.

This part is now an International Standard (IS) and specifies the requirements for the exchange of building element shape, property, and spatial configuration information between application systems with explicit shape representations, specifically the physical parts of which a building is composed, such as structural elements, enclosing and separating elements, service elements, fixtures and equipment, and spaces.

In addition, other parts of STEP have been developed contributing to the release of standard models related to the building and construction industry, e.g., AP228 (ISO 10303-228) Building services: Heating, Ventilation and Air Conditioning (HVAC) and AP230 (ISO 10303-230) Building structural frames: Steelworks.

Also in Europe, the European Committee for Standardization (CEN) has been supporting the development of STEP in the WG2 of its TC310, which is working in line with ISO. CEN/TC310 is responsible for the development of the Standards required by industry for the integration in Advanced Manufacturing Technologies (AMT) systems, such as those required in the areas of Enterprise Modeling and System Architecture, Communication, Data, Information processing, Control equipment, Mechanical and System operational aspects. In other regions of the world, similar committees exist.

Moreover, in the mid 90s the Industrial Alliance for Interoperability (IAI) was created with the purpose of enabling software interoperability, providing a universal basis for process improvement and information sharing in the construction and facilities management industries (AEC/FM). Consequently, IAI developed the Industrial Foundation Classes (IAI/IFC) as an open standard model to allow software vendors to create interoperable applications via the IFC file format. The ISO EXPRESS language (STEP-11) was adopted by IFC to describe its models.

At the same time, the Part Library Usage and Supply - PLUS project - developed an exchange format for intelligent electronic catalogues, based on a common information model facilitating integration with third parties software. The results of this project contributed to the International Standard ISO13584: PLib (Parts Library). PLib intends to contribute to a solution for an electronic catalogue representation in proprietary formats, providing a tool for independent standard representation and supporting multi-representation and integration of different supplier catalogues. It uses a consistent exchange and product modeling format, in this case based on ISO10303 STEP.

2 INTEROPERABILITY IN THE CONSTRUCTION INDUSTRY

For as long as a decade, researchers and software industry are trying to push technology that would allow information interoperability and data integration across the whole construction life-cycle, mostly using standards-based solutions [4][5]. The approaches have essentially adopted a paradigm that is centered on product data [3][9]. Thus, for a seamless integration of information and data in a construction or engineering project, a repository of the product data must be physically or virtually built supported by Standard Data Access Interfaces (SDAIs) (Figure 1).

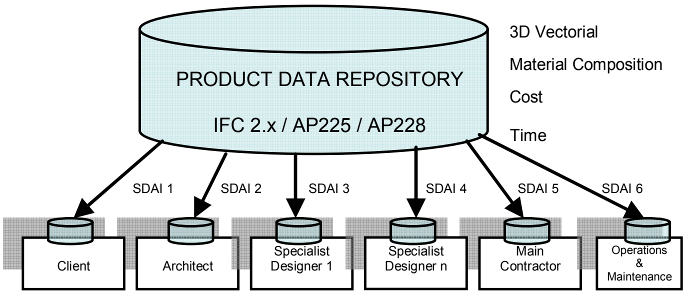

Figure 1 - Product-based repository, in a construction scenario

Despite all the research and practices efforts, the reality has proven that, although feasible, this technological approach is difficult to implement [2][6][11][24]. Indeed, people normally see their work and activities as part of processes, and the product-based integration paradigm requires a discipline of working around a product model, with processes changing to accommodate the need to fulfill the data repository.

Main conclusions from studies thus support the idea of the importance of governance structures in construction networks – mainly the role of the client – in enforcing new ways of working. This is hardly achieved in common, i.e. smaller and shorter term projects, or less knowledgeable construction players [13][14][15][16].

Regarding the wide dissemination of integration of digital data, some authors argue about what will be the “tipping point” for construction companies [7].

The argument made is that if most business factors are far from supporting or enabling the adoption of product-based e-platforms in construction projects, in order to reach the “tipping point”, researchers should seek technologies that are more aligned with the constraints of current construction companies’ infrastructures, relationships and networks.

3 MODEL DRIVEN ARCHITECTURE AND SERVICE ORIENTED ARCHITECTURE

The Model Driven Architecture approach is specified to allow an information model to also be able to work with various software platforms, meaning support to changes on the Operating System, programming language, data storage type or concept (e.g. data warehousing), data servers, data formats and types, networked-based systems implementations, communication levels standards and protocols, all the myriad of elements that form an interoperable application’s working software basis [1][20][21][22].

In the base step of defining an MDA we find the CIM (Computation-Independent Model), which is the most abstract model of the system, representing the system domain. It’s abstraction degree is such that it is often not specified on the definition of the MDA [18].

MDA allows design-time interoperability, in which the core idea – the system Model, also known as PIM (Platform Independent Model) – is defined as a conceptual model based on visual diagrams, use-case diagrams and metadata using the standards UML (Unified Modelling Language), OCL (Object Constraint Language), XMI (XML Metadata Interchange), MOF (Meta Object Facility) and CWM (Common Warehouse Metamodel) [12][21].

A Service Oriented Architecture (SOA) combines the capacity to invoke remote objects and services with tools for dynamic service discovery, placing emphasis on interoperability.

The emergence of web services represents a step forward in the evolution on e-business. Its technical format ensures each of these self-contained business services is an application with a public standardized interface that will easily integrate with other services (from the same or different companies) to create a complete business process. This interoperability allows businesses to dynamically publish, discover and aggregate a range of web services through the Internet to more easily create innovative products, business processes and value chains.

Web services are based on the potential of the combination of XML (Extended Markup Language), a description of the network services as a set of endpoints operating on messages - WSDL (Web Services Description Language), registration of services in a registry – UDDI (Universal Description, Discovery and Integration) is normally used, and a communication protocol - SOAP (Simple Object Access Protocol). SOA needs a platform-independent model for services that address the service business requirements and represents the functionality of the services.

The service model can then be used to generate platform specific models, which are dependent of the platform. Web services are now widely used in B2B applications and MDA can employ web services as a target platform for implementing software systems.

MDA gives us the opportunity to bring web services to a higher level of abstraction, adding agility, flexibility, as well as a higher level of quality and robustness, due to the more formal and accurate specification of requirements and design. Having web services developers program directly to these technologies invites rapid obsolescence and is also far too labor-intensive [10].

One of MDA strengths lies in separating the business logic of the company from the technology infrastructure. MDA makes a clear distinction of implementation details and business functions. So, the technology change can be managed straightforward and when a requirement changes the business behavior, we are able to model this change in the abstract level and it will be directly mapped to our system.

By adopting this approach, companies can rapidly adapt to changing technology landscapes, without having to invest heavily in a great number of developers and operational personnel to support the new technology. Thus, because the business logic is encapsulated, it can be applied to different technology deployments like J2EE or .Net, resulting in a usable source code. This provides a strategic competitive advantage for a company that has to react quickly.

Adopting this paradigm, MDA and SOA can challenge construction and provide an adequate approach, overcoming the shortfalls of the traditional product-based approaches.

4 SHIFTING CONSTRUCTION INTEROPERABILITY PARADIGM

The introduction of MDA and SOA on information systems solutions for the construction sector means that it will be possible to shift from a product-based data model paradigm to a process-based, services oriented object data model paradigm.

Thus, construction players like clients, architects, specialist designers, contractors and suppliers will not need to change the way they work in order to electronically exchange information and data of the project. Rather than building a product data repository for each project, the players will need to access a repository of e.g. web services that support their common interaction processes (Figure 2) [25].

Moreover, most of the research work carried out so far, namely on STEP and IFC driven projects may be reused in the emerging technological context of MDA and SOA, supporting the creation of PIMs in the construction sector business situations.

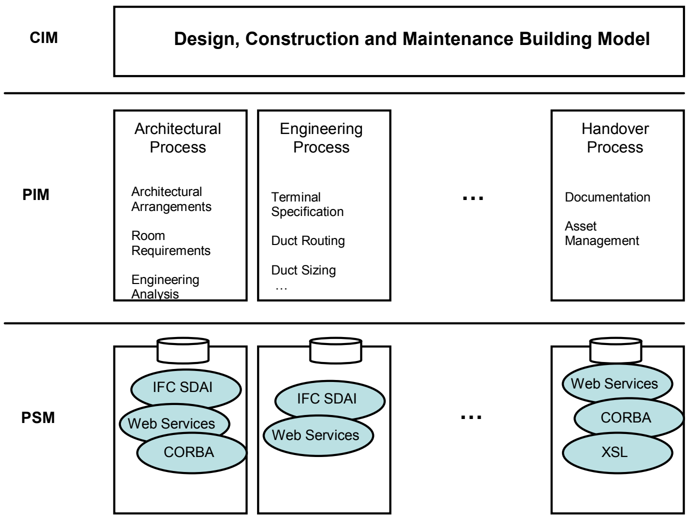

Figure 2 - Services-based Repositories

A HVAC specialist consultant and an Architect Company exist at different locations and are using different business models. At a certain point in their lifetime a Client contracts both companies to build a large office building. This means that they will need to interoperate, building a strong business cooperation model, supported by integrated electronic exchange of information.

Their collaboration is bound to the use of Service Oriented Architectures, but the service implementation is based on different underlying system architectures. Each one has its own services available and with well defined entry-points.

The specialist consultant is using web-services and the architect is using CORBA (figure 3). Regarding the type of information, the first needs the layout and properties of the rooms in the building – called here Service Y - in order to be able to produce the engineering analysis regarding air flows – Service X. Thus, there is a need for a Service Broker in order to produce the composition of services.

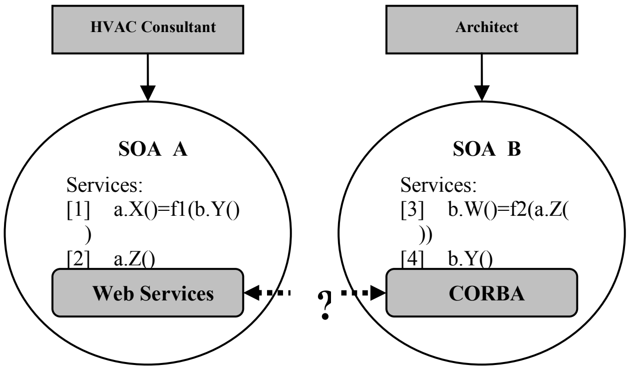

Figure 3 – Interoperability problem at services level

Should the services be implemented in the same system architecture and there would be no problem. But in this case we have services built in two different system architectures. Each company uses its own platform, and different proprietary applications, though allowing external communication of data. Here is the point were MDA adds its great value to make a seamless integration of services.

Traditional approaches would mean that the applications of each company could exchange data through a specifically developed interface. As stressed before, the SOA approach can be a solution for interoperability, but it requires a platform independent model.

Thus, in this example, the brokerage service of the SOA through the MDA approach can be determined by a CIM – e.g. the Process Protocol (see e.g. [19]) - a PIM that determines the various processes and activities involved in the Architect – HVAC Specialist Consultant interaction [17], and a repository of PSMs, with CORBA, Web Services, SDAI, etc. related services (Figure 4), that support application specific interoperability.

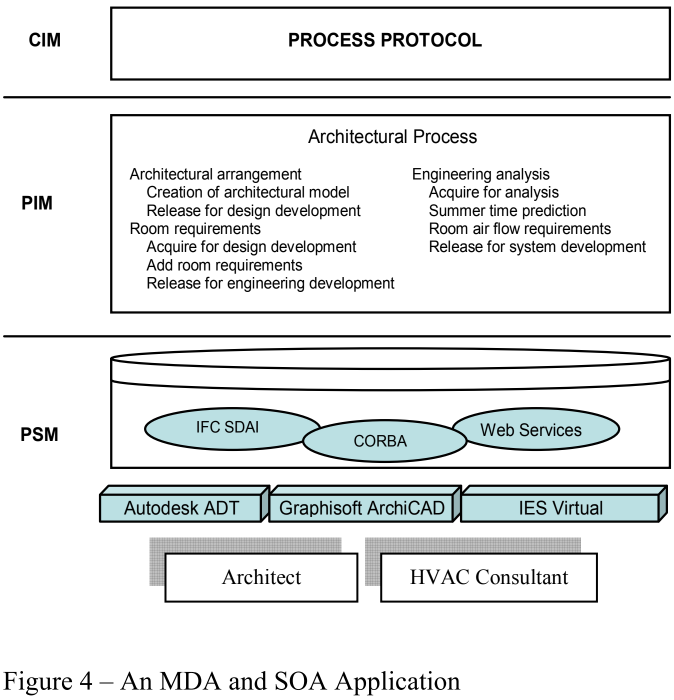

Figure 4 – An MDA and SOA Application

The service definition does not need to be unique for this business relationship. Indeed, this type of process and exchanged information is very common in any project and thus the CIM and PIM could be generically used by both parties in other business transactions.

Transforming the high-level models to a concrete entire IT Infrastructure, it can be created services and SOAs that are decoupled from the lower level platforms, infrastructures and implementations, opening the way to seamless interoperability.

This would mean that functional applications would have access to a pool of normalized and interoperable services and SOAs that translate common information transaction needs between construction parties and through service brokerage, and obtain the seamless integration.

4.1 Validation of the integrated environment

Conformance and interoperability testing are procedures that should be performed to validate and assure the quality of the global integrated system, as a monitoring procedure or when a new application is plugged in. This issue is even more sensitive when different standards (e.g., Application Protocols) are concerned, and semantics and harmonization of concepts and structures have to be realized. In advent of the Model Driven and Services Oriented Architecture, where it is expected many of the interoperability issues to be solved, this would be a major challenge to face.

Validation procedures should be performed after developing the interfaces to the services to assure conformity of the application with the adopted standard. Also, to assure a complete interoperability with all other parties integrated in the global system, verification and validation should be performed between one application and all parties in order to assure a reliable exchange of information conforming to the standard, syntactically as well as semantically.

After one application develops an interface, validation procedures should be executed to assess conformity with the adopted standard. Also, to validate interoperability between one application and the others in the integrated global system, syntax and semantic validation procedures should be performed among all parties, to guarantee a reliable exchange of information conforming to the standard. In this way, conformance testing (CT) and interoperability checking (IC) are mechanisms that should be performed to validate and assure the quality of the global integrated system, as a monitoring procedure or when a new party is plugged in. This issue is even more sensitive when different standards (e.g., Application Protocols) are concerned, and semantics and harmonization of concepts and structures exist or have to be realized.

Validation is directly related with the fact that erroneous assumptions in the early phase of development (e.g., data modeling) can cause correction work in later stages. To guarantee the syntactical correctness of a data model with a standard is not the main problem because it comprehends the complete formal description of its methods and grammar, and parsers are usually available. However, the main difficulty is typically related when dealing with semantics. The more semantics are included, the more complex the conceptual data model becomes, and so more difficult the correct interpretation of the model by all applications willing to adopt it.

4.2 Methodology for the development of an ATS

Considering a System Under Test (SUT) adopting an AP, e.g., a CAD system, the developed processors implementing the interface with the standard model, i.e., the Implementation Under Test (IUT), should be verified through a set of Abstract Test Suits (ATS). In case of success, this IUT can be certified as compliant with the standard AP. Systematizing the contents in parts 30s of standard ISO10303, an ATS should be developed and released, tied with an AP to support the validation procedures of a standard AP implementation.

In general terms, an ATS describes the procedures, and respective verdict for verification and validation of an application that implemented a translator to adopt an AP. This ATS is defined by a set of Abstract Test Cases (ATC) describing in a conceptual format, e.g., in free text, what kind of tests should be executed, how to proceed, and what the inputs to apply should be and what the correspondent expected outputs are, i.e., the Input Data Specification (IDS) and its associated verdict.

To execute the physical test to validate the system, the ATS needs to be instantiated creating the Executable Test Cases (ETC), which are the data and commands to be used to execute the test described in computer format.

With the ATS defined for one AP, the Conformance Testing procedures can be executed on the IUT. This test is executed twofold: one to validate the implemented pre-processor, and another to validate the post-processor. The pre-processor validation starts introducing in the internal data structure of the application the case as described in the ATS to be validated, e.g., piece of furniture. This input should be performed using the available application's commands, and usually done manually. Next, the pre-processor is activated to generate the correspondent data in standard format. Its result is analyzed in terms of syntax, structure and semantics, and the resultant file directly compared with the pre-defined expected result stored in the ETC database.

To validate the post-processor, one of the examples stored in the ETC database is used as input to the IUT. After the SUT import the ETC example, a set of queries to the SUT is executed in order to analyze the respective response, and check its correctness in terms of semantics. A typical example is to set the system importing one product representation, and later to analyze it according to several presuppositions to validate the semantics.

This methodology and architecture for CT of APs may also be adopted when developing multilevel application protocols. Indeed, considering that each module is already tested and certificated, this approach hopes to reduce the effort when validating the integrated multilayer AP, compared with the necessity to validate the complete integrated AP from scratch.

4.3 Internet-enabled conformance testing environment

When one application is adopting a standard and developing its translators, it is important to have access to tools that can validate the implementation and check if it is compliant with the standard. Such validation tools are of some complexity, and sometimes it is not practical to have them installed in all platforms and operating systems where the translators are in development.

To give support to any implementation adopting standard APs, we propose an internet-enabled conformance testing environment, adopting a Service Oriented Architecture, as well. This environment would be established in a web-server and use internet-based services for its access which could be done anywhere through the net.

In the core of this platform there is a compiler offering most of the mechanisms needed to perform model validation through the standard and model's rules and constraints. On top of it, extensions were developed to make them available through web-services to the implementers. Major services are data check and services raporteur.

When the implementer would like to validate a translator (the IUT) in development, he/she can submit the respective standard data file to the server, receiving by return the respective validation report. Because the validation procedure can take a long time, and to avoid having the user waiting on the net at submission time, when the job is done and the report completed, the server sends back an email message notifying him that the report is ready and available for download.

5 CONCLUSIONS

The construction industry, due to its structure, dynamics and characteristics of its companies and business relationships has been laggard as far as interoperability is concerned.

The emerging MDA (Model Driven Architecture) paradigm has been evolving and becoming the standard way of handling middleware and infrastructure development for enterprise systems groups. The developments towards greater interoperability has also been supported by the Service Oriented Architecture (SOA), that combines the capacity to invoke remote objects and functions/services with tools for dynamic service discovery.

The paper stresses that construction business systems integration through interoperability are likely to be better attained with the benefits of enhancement of SOA with MDA. This combination provides flexibility and rapid deployment, but maintaining current business processes, and thus enabling a faster adopting of e-platforms by constructions companies.

Conformance and interoperability testing are procedures that should be performed to validate and assure the quality of the global integrated system, as a monitoring procedure or when a new application is plugged in. In advent of the Model Driven and Services Oriented Architecture this would be a major challenge to face.

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