Methodology for Seamless Supply Chain Planning

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Abstract. Today, enterprises are typically in a constant process of acquiring and updating its information technologies, however typically without an overall view of the global inter and intra enterprise's system integration. Researchers have been proposing methodologies and platforms to assist such integration of applications and data. However, implementing new technologies in organizations is a difficult task, since its quality needs for architectures development are more exigent and critical than ever, due to the systems complexity, dimension and to the interoperability requirements to interact with third party applications and infrastructures. This paper proposes a methodology for seamless Supply Chain Planning (SCP), by using a domain reference ontology, data model representation standards, software components evaluation and interoperability checking processes. The methodology VALTE is used to assure that enterprises use tools for SCP compliant to semantics, represented in a common reference ontology, created by the MENTOR methodology. These two horizontal methodologies are vertically supported by interoperability checking processes, which assure an interoperable supply chain planning system.

Keywords: Interoperability Checking; Semantics Interoperability, Quality Assurance, Supply Chain Planning.

1 Introduction

The globalisation of markets and manufacturing has forced the management of supply chains not only consider business processes in the traditional value chain, but rather processes that penetrate networks of organisations. The formation of cooperation and collaboration alliances between several small organizations is proving, in multiple cases, to be more efficient and competitive by comparison with big companies. Thus, the research on supply chain management has turned from an intra-enterprise focus towards an inter-enterprise focus [1].

Supply chains consist of different structures: business processes and technological, organizational, technical, topological, informational, and financial structures. All of these structures are interrelated and change in their dynamics. To ensure a high responsiveness level, the supply chain plans must be formed extremely quickly, but must also be robust. That is why it becomes very important to plan and run supply chain plans in relation to all the structures. The increasing competitive pressures coupled with the rapid advances in information technology have brought supply chain planning into the forefront of the business practices of most manufacturing and service organizations [2]. Consequently, there has been a growing interest in electronic business (e-business) solutions

to facilitate information sharing between organisations in the supply chain. However, partnerships cause some problems mainly in integrating Product Life Cycle phases, since manufacturers, distributors, designers, retailers, warehouses, often acquire their proprietary solutions which are, typically, not interoperable with another [3].

Due to the large number of worldwide available software components in a specific business domain, each enterprise has its own software, thus when it is needed to do business with other enterprises in the same domain, application and data interoperability problems emerge. Quality evaluation of the developed components and of the underline communications is paramount, for that this paper proposes VALTE for the components evaluation and interoperability checking required to test organization communications conformability.

Standardisation in data structures appeared to solve the referred communication problems. Several initiatives were taken to address this issue, like ISO10303. ISO 10303, also known as STEP, is the standard for the exchange of product model data. STEP Application Protocols have been widely used in industrial environments, to support systems interoperability through the exchange of product data in manufacturing domains. However, this kind of data representation standards did not solve all the problems. Semantics interoperability problems still to be solved. More recently, the development of ontologies, as promising techniques with capabilities to solve semantic issues, has been addressed by important companies and SMEs. Thus, each company is struggling to develop competencies at this ontological level, but inevitably different perspectives will lead to different final results, and achieving different ontologies in the same business domain is the reality. One possible solution is to have a reference ontology for a specific domain where all the domain enterprises should use in their business. Although, to force manufacturers or suppliers to adopt a specific ontology as reference is not an easy task, since each enterprise does not foresee any outcomes by changing their knowledge. Thus, an advantageous solution would be to let them to keep their terminology and classification in use, and adopt a reference ontology. The adopted ontology will be the organization knowledge front-end, enabling inter-enterprises communications sharing the same terminology and semantics. Since this reference ontology will become their front-end, each organizational enterprise should feel motivated to participate in its building process, contributing with their own terminologies, definitions and classification structure.

1.1 Methodology to enhance inter-enterprises SCP interoperability

System methodologies for enterprise interoperability facilitate organizations to keep its technical and operational environment, improving its methods of work and the usability of the installed technology through quality assurance of the system software components, ontological harmonization of the enterprises product models in use, assessed by a fitting validation framework for conformance testing and interoperability checking.

In order to have an enterprise organizational system interoperable, it has to have a domain reference ontology which enhances inter-enterprise's semantics interoperability concerning to the contents of a standardized data representation model. These both components (reference ontology; data representation model)

should be complemented with software quality assessment and Interoperability checking methodology able to make the model conformance testing (Fig. 1).

The paper proposes the integration of the VALTE (section 2) and MENTOR (section 3) methodology, complemented by interoperability checking methods (section 4), to contribute for seamless supply chain planning (section 5). The paper finishes discussing a case study in an industrial context.
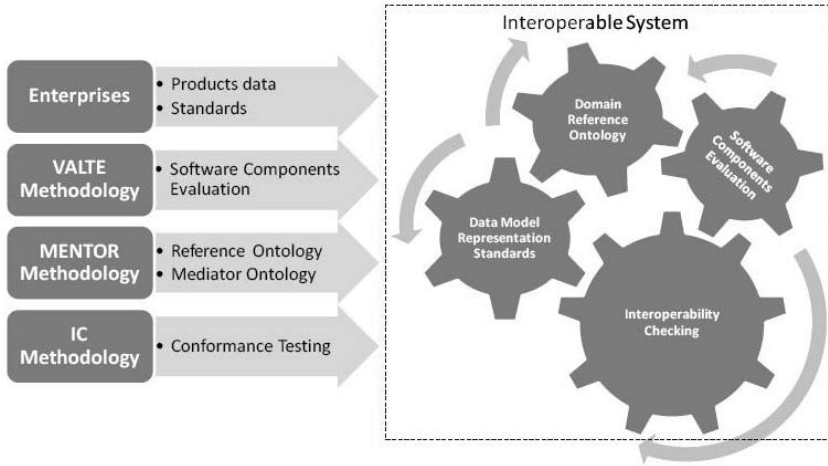

Fig. 1. System interoperability methodologies.

2 Validation and Testing of Supply Chain Software Components

The essential parts of software quality evaluation are the quality model, the method of evaluation, software measurement, and the supporting tools [4]. To develop good software, quality requirements should be specified, the software quality assurance process should be planned, implemented and controlled, and both intermediate products and end products should be evaluated [5].

VALTE is an evaluation methodology for supply chain software components, using as reference the Software Product Quality Evaluation Reference Model that describes the process, activities and tasks performed during the quality evaluation of a software product. This reference models is defined by the standard [6] that contains general requirements for specification and evaluation of software quality and clarifies the general concepts providing a process description for evaluating quality of software product, stating the requirements for the application of the evaluation process. This specification is part of the SQuaRE series of standards created by ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission). SQuaRE replaces the current [7] series and the [8].

The VALTE methodology reference details the activities and tasks providing their purposes, outcomes and complementary information that can be used to guide quality evaluation of a supply chain software component. To evaluate the software quality it is needed, first to prepare the evaluation, then establish the evaluation requirements, specify, design, execute and, finally, report the evaluation (Fig. 2).
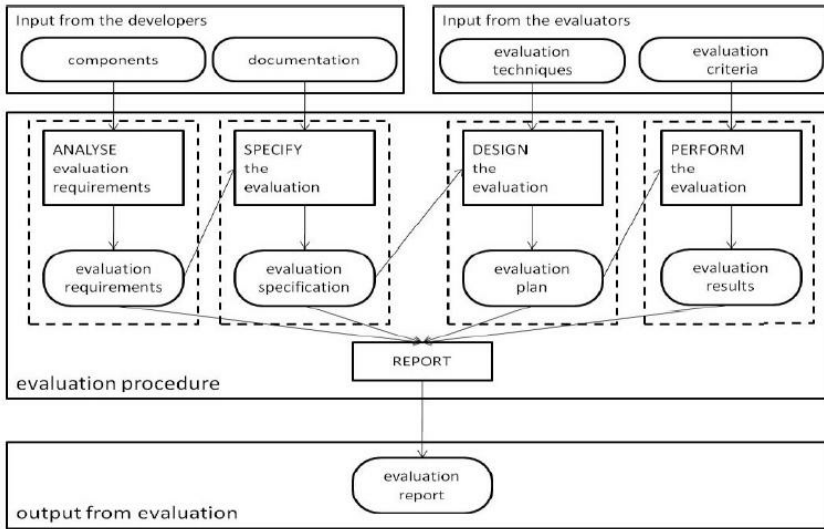
Fig. 2. Information flow and activities of the VALTE evaluation methodology.

The developers must provide as input the components and their documentation, in the other hand the evaluators should define the evaluation techniques and the evaluation criteria, in this paper the evaluation is defined by the VALTE methodology for a supply chain software component [9].

The principal motivation for using a standardized methodology when performing evaluation activities is to promote the following desirable evaluation process characteristics:

Repeatability: repeated evaluation of the same component to the same evaluation specification by the same evaluator should produce results that can be accepted as being identical;

Reproducibility: evaluation of the same component to the same evaluation specification by a different evaluator should produce results that can be accepted as being identical;

Impartiality: the evaluation should not be biased towards any particular result;

Objectivity: the evaluation results should be factual, i.e. not coloured by the feelings or the opinions of the evaluator.

The evaluation procedure comprises a number of steps (ANALISE; SPECIFY; DESIGN; PERFORM) which divide the evaluation into discrete activities. The evaluation requirements are formal records of the agreement between the producer of the software and the evaluator of what is covered by the evaluation process. It provides a list of software characteristics which is to be evaluated, their evaluation level and it identifies the source of data and evidence which can be used in the evaluation process. The evaluation specification, besides the more formal description of the evaluation requirements it consists on the identification of the received documents and classification of the available items into product, process and supportive information, in order to identify which evaluation techniques can be applied. The evaluation plan includes the list of evaluation modules to be applied and that will guide the evaluation activities. The evaluation results will be stated based on the metrics and measures defined

and the positive or negative response of the software components to all the tests performed.

The intended of this evaluation strategy is to be a guide when actually running architecture evaluation activities. For that it contains a level approach to quality characteristics and a flexible view on classifying components and process information. The evaluation methodology is designed to support the evaluation of all architecture components without need for modification of its basic principles. This will provide a more balanced and equal evaluation result of all the components of the architecture.

VALTE identifies relevant evaluation techniques in order to have a set of applicable Evaluation Modules (EM) defined and applied to evaluate supply chain planning architectural components proposing seven evaluation modules according with the evaluation techniques defined for each quality characteristic. These modules describe and guide the evaluators when performing the evaluation of architecture components: EM1 - Functionality: Functional Test Cases; EM2 - Functionality: Unit Tests; EM3 - Reliability: Fault tolerance analysis; EM4 - Usability: User interface; EM5 - Efficiency: Execution time measurement; EM6 - Maintainability: Inspection of documentation; and EM7 - Portability: Analysis of software installation procedures.

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3   Enterprise Reference Ontology for Interoperability

The enterprise reference ontology development follows the MENTOR methodology. Its main objective is to help an organization to adopt or use and to build, a domain reference ontology, after through several main steps as semantic comparisons, basic lexicon establishment, mappings among ontologies and others operations on knowledge base representations [10].

The method to support the development of a common reference ontology for a group of enterprises sharing a business domain, provides several steps as semantic comparisons, basic lexicon establishment, mappings among ontologies and other operations on ontologies. This method is composed by two phases with three steps each (Fig. 3): the Lexicon Settlement - Phase 1 (steps: 1; 2 and 3), and the Reference Ontology Building - Phase 2 (steps: 4; 5 and 6). All of these steps are deeply described in the following two pictures where each step has a set of actions which has a number related to the step which belongs to (e.g. 1.1 is an action of the step 1).

The Lexicon Settlement phase (steps: 1; 2 and 3) represents a domain knowledge acquisition which comparatively to the human language apprentice phase could be represented in computer science as a semantic organized structure with definitions.

The thesaurus can represent such words structure of associated meanings and thus should be built in order to establish the lexicon of a specific domain. This

phase has three steps: Terminology Gathering (step 1); Glossary Building (step 2) and Thesaurus Building (step 3). These steps define a set of workflows that establishes a thesaurus of the domain before starting the ontology building.

Figure 3 (left part) depicts the state diagram of the lexicon settlement phase. The terminology gathering step concerns to the process of collecting all relevant terms (action 1.2) in a specific domain previously defined (action 1.1). All the participants in the process should give their inputs. There is no rule from where the terms should come. Since they are related with the domain established. Tools for automatic extraction of domain related terms can be found, nevertheless there is always need of a human checking before close the terms list to not miss any domain terms. All the terms provided from the contributors are acceptable in this step (action 1.2). Nobody has authority to erase other's participant term. The term should be collected with reference to the contributor in order each contributor provide term's annotation in the next step (action 2.1).
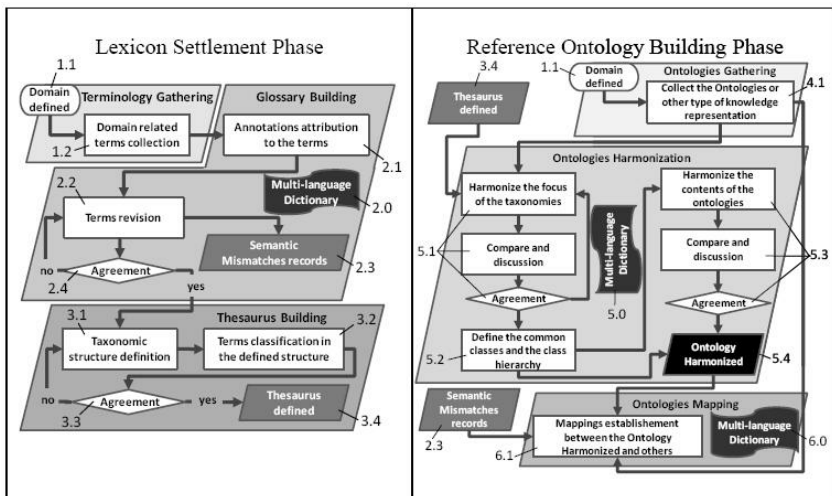

Fig. 3. MENTOR Phases and steps.

Glossary is a specialized vocabulary with corresponding annotations. This vocabulary includes terms that are unique to the subject, have special meaning in the field of interest. The annotations include descriptive comments and explanatory notes for the terms, such as definitions, synonyms, and references. A Glossary can be used when communicating information in order to unify knowledge sharing. The Glossary Building step (step 2) intends to build a glossary in the domain defined. It starts with annotations attribution (action 2.1) to the terms collected. Each contributor should provide the annotations for his own terms. After having all the terms provided with annotations, it proceeds to the terms revision cycle (actions: 2.2; 2.3 and 2.4). In this cycle it could be useful to use a multi-language dictionary (action 2.0) in case of the organization members don't use the same natural language. The dictionary will help translations to the agreed language for the reference ontology. The terms revision process can have semantic and syntactic cases of mismatches (action 2.3), where they are recorded as a semantic mismatch for future mappings using the proposed mediator ontology.

After a careful revision in all the terms (action 2.2) with a successful agreement (action 2.4) in their meaning consolidation, the glossary is defined from the terminology list in the domain specified. Another output from this process is the semantic mismatch records (action 2.3): this is made using the Mediator Ontology.

The Thesaurus Building step (step 3) is composed by a cycle where firstly, the knowledge engineers define a taxonomic structure (action 3.1) from the glossary terms, establishing some as thesaurus node terms. Secondly, the other terms are classified to the right paths in the existent taxonomic structure, being the thesaurus leafs (action 3.2). If there is an agreement (action 3.3) in the structure and in the terms classified, the thesaurus is defined (action 3.4). If not, the cycle starts again from the taxonomic structure definition (action 3.1). The thesaurus defined will enhance the ontology harmonization process in the next phase.

The Reference Ontology Building phase - Phase 2 (steps: 4; 5 and 6) is the phase where the reference ontology is built and the semantic mappings between the organizational ontologies and the reference one is established. Figure 3 (right part) describes this.

The first step comprehends ontologies gathering (action 4.1) in the previously domain defined (action 1.1). Other type of knowledge representation could be used as input for the harmonization ontologies process together with the thesaurus defined (action 3.4) in the previous phase. The harmonization method for building ontologies, proposes the development of a single harmonized Ontology's by two cycles (actions: 5.1 and 5.3) where first the structure is discussed until having agreement on it (action 5.1), which result on the definition of the common classes and the class hierarchy (action 5.2), and then the same process for the ontology contents definition (action 5.3). From this process new semantic conflicts could be found. After agreement, the resolution could be recorded in the Mediator Ontology for further mapping establishments. With all the agreements accomplished, the harmonized ontology is finalized (action 5.4) together with the mapping tables (action 6.1), describing the ontological relationships between the harmonized ontology and each one of the individual ontologies through the use of the semantic mismatches records (action 2.3).

Semantic difficulties related to the natural language of the potential users of the harmonized ontology are likely to happen. To assist on it, the ontology is complemented with a multi-language dictionary where a set of normalized tokens gives the reference to the corresponding concepts and definitions in different native languages (actions 5.0 and 6.0).

4 Interoperability Checking

During latest years, the architecture of the STEP Application Protocols has been revised to promote the reuse of software components, where the testing and quality assurance plays a critical role in the implementation of the STEP software components when applied to different types of manufacturing and e-Business systems.

Interoperability Checking (IC) plays an important role to the company's systems, providing an appropriate mechanism to check if they are able to seamless exchange information between them. The methodology proposed for

the presented case is based in the development of an Abstract Test Suite (ATS) that is used to define the set of tests to be used to verify the interoperability between the systems. Figure 4 shows the diagram with the methodology for validation, in this case considering to systems in validation, i.e., "Computer System" and "IC System".

To guarantee the systems interoperability, these steps would be executed to all the cases defined by the ATS [11]. As depicted, the first step consists in reading a XML file provided by the "IC System". Also, the file must be validated with the Conformance Testing (CT), depicted in the system validation section. After the "Computer System" read and "understand" the information in the file, the "Computer System" modifies it with new information and send it back to the "IC System". Then, the "IC System" analyses the modified file, also improving the CT, and confirms (or not) it is able to understand the modified information that received from the "Computer System".

If the information is correctly in the modified file, the IC can notify company that their systems pass the current test. Then company must pass to the second test, executing the same steps. Doing all the defined test files, IC can ensure the Interoperability of the company's system. This service will be available online, allowing the users to download the test files and check its system. The upload of the modified files will be done by email to the community IC system. After complete the verification of the received file, the community IC system, will notify the user of its interoperability with other complaint systems.

5 Case Study

In order to guarantee the survival in today's competitive and demanding digital world of business, the European companies, especially SMEs, should be more agile, self-sustainable and responsive to the changes in the supply chain. Obtaining and maintaining a competitive edge in supply chain is not only the concern of individual SMEs, but should be also addressed by the entire chain jointly. The supply chain partners should collaborate effectively so as to better align supply and demand forecasts to have a joint strategy for handling exceptions that will occur in the way of realizing the "the network is the business" vision.

The simple choice of furniture components suppliers by a furniture manufacturer brings interoperability problems. Suppliers have defined various nomenclatures for their products and its associated knowledge. Thus, the need to align applications, to exchange products data and semantics emerged as a priority to solve the dilemma.

Figure 4 describes the validating scenario, where a set of enterprises agreed to work together to supply a big common client with various furniture products which are built collaboratively.

The first step is to follow the VALTE methodology (left part of the Fig. 4), which will guide the applications evaluation activities. The evaluation follows a plan that includes the list of evaluation modules to be applied against the defined requirements related to the desired level of the software components characteristics. The evaluation results are then stated based on the metrics and measures defined and the positive or negative response of the software components evaluation to all the tests performed defines if the applications belongs to the set of common tools for a specific supply chain planning.
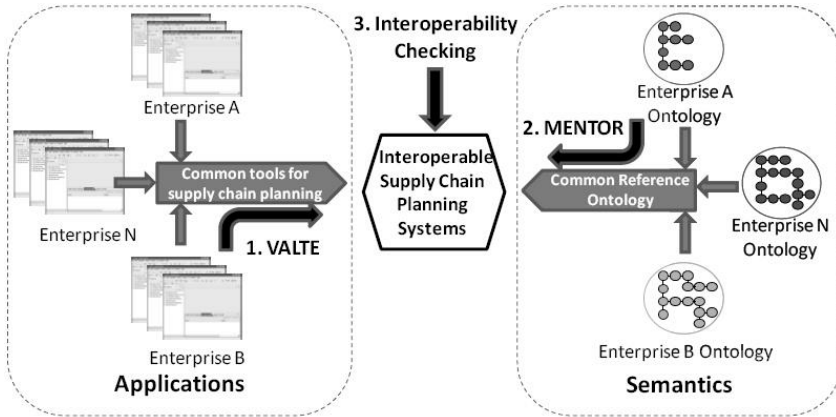
Fig. 4. Case Study overview.

In the second step it is developed a reference ontology to the enterprises that are working together in this supply chain to establish between them a common semantics (right part of the Fig. 4). The MENTOR methodology is used to develop such reference ontology. During the reference ontology building phase, it is produced a mediator ontology which records all the semantic operations performed in this process. One of the applications of these semantic operations logs is to use that recorded information for semantic translation. One possible example of such process is when a message with a product request is sent to Enterprise B. The mediator ontology is used to get the "semantic translation" of the information present in the message, which uses syntax accordingly to the reference ontology, to the equivalent syntax used in the Enterprise B.

For instance, the request of "Compact Beds" with "Light Decorations", is translated to a request of a "Juvenile Bed" that have the "Electric Equipment" attribute as a "Lightning Decoration". Nevertheless these mappings are related only to literal elements (product classes). However, the complexity increases when the mappings are established between property elements, which result in some complex transformations. Back to the same example, the request of a product classified as "Compact Beds" of a "size=3", where "size" is a property in the reference ontology, is "translated" to a "Juvenile Bed" product with a "dimension" which "size" is characterized by a "length" with a value "180" and a "width" with a value "90". Figure 6 depicts an extract of the reference and enterprise B ontologies where the referred mappings are related to.
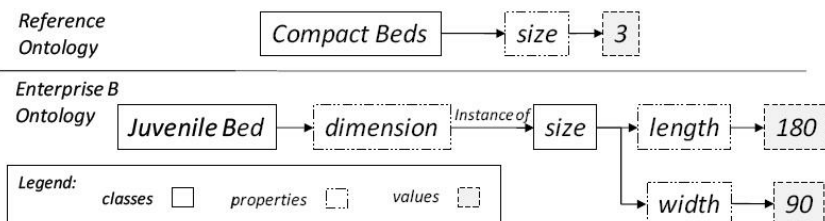

Fig. 5. Extract of two ontologies where mapping relations were established.

The transformation resulted from the mapping of this example can be recorded in the mediator ontology as a mathematical expression, that in this specific case is based on the equations presented in the following.

$$FR(x) = size(x) \tag{1}$$

$$FE(y,z) = dimension(size(length(y),width(z))) \tag{2}$$

$$FR(x) = FE(y,z) \tag{3}$$

$$size(x) = dimension(size(length(y),width(z))) \tag{4}$$

$$size(3) = dimension(size(length(180),width(90))) \tag{5}$$

$$y = 120 + 20x \tag{6}$$

$$z = 60 + 10x \tag{7}$$

$$FR(x) = FE(y(x),z(x)) \tag{8}$$

$$size(x) = dimension(size(length(120+20x),width(60+10x))) \tag{9}$$

Equation 1 indicates a function that represents the "Compact Beds" property element, which in this case is related to more than one property in Enterprise B representation (equation 2). In order to define the transformation which relates both representations, it is stated an equality between both expressions (equations 3 and 4). After analysing empirically all the existent values that these expressions could take (equation 5 shows one case), it was defined two linear equations which relates them (equations 6 and 7). At the end it was reached an expression that establishes a semantic relation between both representations and establishes the transformation equations related to each variable (equations 8 and 9).

To ensure the interoperability between the systems, the third step on this use case, it is applied the Conformance Testing (CT) to its exchanged files. Based on the defined methodology for CT, the architecture shown in the Figure 6, is used to validate such files. The architecture was designed based in web-services, able to receive the files in XML format and checking them against the reference testing model using an Application Engine developed in JAVA, SAX, Schematron and XALAN.
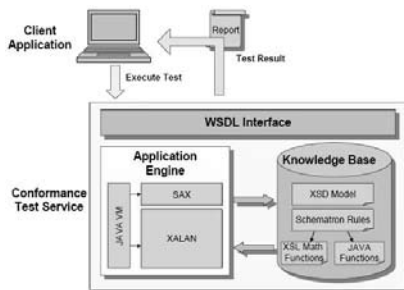

Fig. 6. Architecture for CT system validation [11].

Using the CT the user can check the files against the defined models, ensuring its correct implementation. The CT checks the XML against syntactic and semantic rules and sends back the detected errors enabling its correction. Following the same example as before, if is defined that an attribute, in the "Compact Beds" entity, named "size" with a value 3 must be related to 90x180 (width, length), and the system detects a relation which have "size=3" with 70x190, the CT with the semantic rules will detect the error reporting it to the user. Also if there is "Compact Bedd" instead "Compact Beds", the CT with syntactic evaluation, will detect and report the error.

With CT executed to its XML files, the next step is the application of the IC. To apply IC, the user will analyze and modify the test files, sent by the IC system, and send it back to evaluation. After check all the files, defined in the ATS for IC, the user receives the confirmation that its system is interoperable. With all the ATS executed (CT ATS and IC ATS), the system validation can ensure that the systems are in conformance with the model defined and is interoperable with others system of this type.

6 Conclusions

The proposed methodology enable the computational systems of any set of enterprises which work together in a supply chain planning to smoothly communicate between each other using syntax and semantic present in data representation standards and in the reference ontology respectively. This is complemented with a previous software components evaluation and a post conformance testing procedures.

The mentioned conformance testing services were applied with good results in a real scenario supervised by the research EuropaINNOVA initiative through the INNOVAfun project (www.funstep.org). These achievements have been encouraging to the development of further framework functionalities in the future, like the generation of the reports according to a normative schema (e.g., defined in EXPRESS and XML), to enable automatic inference and reasoning on the errors found, and provide automatic correction of the identified errors by an expert system. Interoperability Checking complements the Conformance Testing ensuring that two or more systems can be seamless compliant. For the future, the authors intend to have available a cloud of web services able to set up knowledge sharing organizations through the web with the conformance testing services.

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