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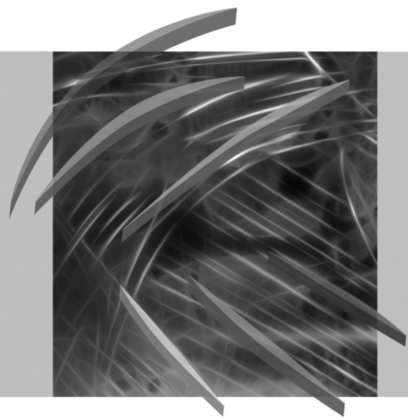

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Intelligent Technologies and Applications

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ONTOLOGIES SUPPORTING THE PROCESS OF SELECTION AND EVALUATION OF COTS SOFTWARE COMPONENTS

Abstract: The general aim of this paper is to present ontologies supporting COTS components selection and evaluation process. The general statements of an ontology project and construction were presented as well. Thus the whole steps of the ontology construction process for COTS were described in details. The exemplary parts of ontologies for methods and techniques, information tools and frameworks, methods and tools for ontology evaluation and COTS ERP software components were presented. Moreover, the formal way of COTS ontology description was provided. The conclusions finish this paper.

Keywords: ontology, COTS software, COTS selection and evaluation, COTS components, COTS methodology.

1. Introduction

One of general issues of building COTS components ontology is to provide systematic knowledge of available COTS components and solutions that support selection and evaluation process. Moreover, the ontologies ensure the freedom in requirements definition process initiated by the user. Then the applications of reasoning search engines allow identifying and selecting that kind of solutions which accomplish predefined user's requirements. The application of COTS ontology enables both the freedom in specification level of obtained results and the selection of components on base of any number of criteria. Furthermore, it allows organizing diffused information about available solutions on the market through providing verbal description of considered methodologies.

The process of building COTS components ontology requires the restriction of the research area to the selected methods and techniques, information tools and frameworks, methods and tools for the ontology evaluation and COTS ERP software components. Then the ontology domain encompasses COTS software solutions mentioned above and the set of methodologies supporting the COTS components

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selection and evaluation process. The provision of a high-level of specification of a given COTS components ontology requires the restriction of research area to COTS ERP components for Management Information Systems (MIS) domain. The aim of the ontology design is to reduce the time necessary for software selection. Moreover, the decision-maker ought not to have a broad and specified knowledge about available software solutions on the marketplace. Then the decision-maker receives both the solution corresponding with the pre-defined set of criteria and the set of detailed solutions with a varied level of specification. The ontology is dedicated to all entities that are looking for information about COTS components, constructors of the information systems on base of COTS components, and for the users looking for information about available methodologies and their appliance as well. Thus, the ontology should include the useful information for the end-users.

The general aim of the paper is to present the ontologies supporting COTS components selection and evaluation process. The knowledge management about COTS software components was provided as well. Then the whole process of COTS ontology construction was presented in details including the general statements of ontology construction. The aim of COTS ontology is to provide a systematic and repeatable knowledge about COTS software components and the methodologies as well.

2. The project of COTS components ontology

The term "ontology" very often is referred to philosophy which defines ontology as a science about existence, types and structures of objects, their nature and train of events, processes and relations between them [Gruber 1993; Fridman-Noy, Hafner 1997]. In information science, an ontology is regarded as a software (or formal description) of artifacts, designed for specified set of usage and computable environment [Smith 2003].

In the literature many approaches to classification of various types of ontology exist, presented among others by O. Lassila and D.L. McGuinness [2001] and by D. Oberle [2006]. O. Lassila and D.L. McGuinness [2001] present a possibility to organize an ontology based on a rising degree of formal semantics whereas D. Oberle proposes an idea of multidimensional fusion [Oberle 2006]. On the basis of these approaches M. Hepp identifies six characteristics of variables of an ontology project: expressiveness, size of relevant community, conceptual dynamics in a given domain, number of conceptual elements in a particular domain, degree of subjectivity in a conceptualization of the domain, and average size of the specification per element [Hepp 2007] (Figure 1).

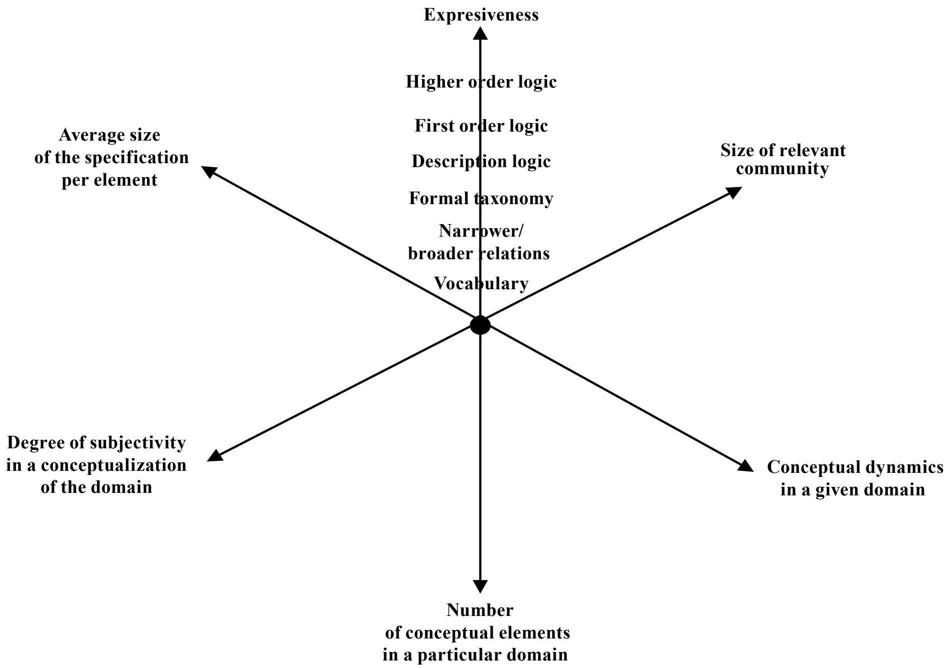

Figure 1. Six characteristics of ontology project variables

Source: own elaboration on the basis of [Hepp 2007].

The first characteristic is defined as an expressiveness of formal description. It enables higher specification level of a given ontology. The next feature encompasses the size of relevant community. The ontologies for a bigger group of users should have different kinds of features than the solutions dedicated only for a small groups or single entities as well. Then conceptual dynamics in a given domain has the following characteristic. It provides the answers how to perform updates and changes of COTS components in the ontology project in an efficient way. The number of conceptual dynamics in a MIS domain determines the necessity of strategy versions and constrains the possibility of actual number of ontology specification. Thereafter the number of conceptual elements in a particular domain (MIS) determines the phase of development of a particular ontology. The bigger ontology, the more difficult it is to depict it graphically. Thus, the high level of ontology development has an influence on reasoner mechanism and it requires in-memory of an ontology model [Hepp 2007]. Then it is necessary to define a size of the COTS ontology. The next characteristic is defined as a degree of subjectivity in a conceptualization of the domain. It determines the existing degree of notions considering particular concepts between different actors. The last feature encompasses the average size of the specification per element which determines the range of a given specification of average size per element. It defines the range of COTS ontology as well.

3. The phases of COTS components ontology construction

In the literature COTS products are defined as ready to sell products, available in many identical or similar copies and the vendor has a total control of the COTS software [Morisio, Torchiano 2002]. COTS products can be a part of a bigger and more complex COTS-Based System (CBS) [Torchiano, Morisio 2004]. COTS products marketplace changes frequently and continuously, hence very often the producers and sellers of particular software lose control of the product and do not cope with updating the information about particular product or components. The ontology for COTS should provide mechanisms for updating the information about particular components and methods and extracting the information about these components according to inquiries posed by a decision-maker.

Generally, COTS ontology should ensure a freedom in requirements definition process and simultaneously provide systematic knowledge about components and available methods. Hence for each group of the solutions: methods and techniques, information tools and frameworks, methods and tools for ontology evaluation and COTS ERP software components the ontology was built. As an input, the user defines the specified preferences the preferable solution should have. Then as an output, the reasoning mechanism provides to the decision-maker the set of selected solutions including methods and techniques, information tools and frameworks, methods and tools for ontology evaluation and COTS ERP software components, which fulfill the pre-defined preferences. As a next step, the user, who is looking for components, can choose proper solutions supporting next parts of evaluation process from methods and techniques for COTS selection and evaluation or information tools and frameworks. The higher specification level the smaller number of results. Furthermore, the process of verification obtained results was assured by analyzing available methods and tools for ontology quality evaluation. Then the ontology of available methods and tools for ontology quality evaluation was proposed as well. The aim of that ontology is to find and apply a proper method or tool to evaluate and verify the quality of a given ontology. The schema presented in Figure 2 depicts the general statement of COTS ontology project.

For each group of the solutions: methods and techniques, information tools and frameworks, methods and tools for ontology evaluation and COTS ERP software components, the identical procedure of building the ontology was adopted. On base of accomplished characteristics of given solutions the set of criteria was defined. It provides a basis for taxonomy construction and then for building the ontology. Moreover, the classes were defined (named as *defined classes*). Defined classes should fulfill the necessary and sufficient conditions. On the basis of reasoning mechanism the selection of the solutions is executed. Then the verification of given

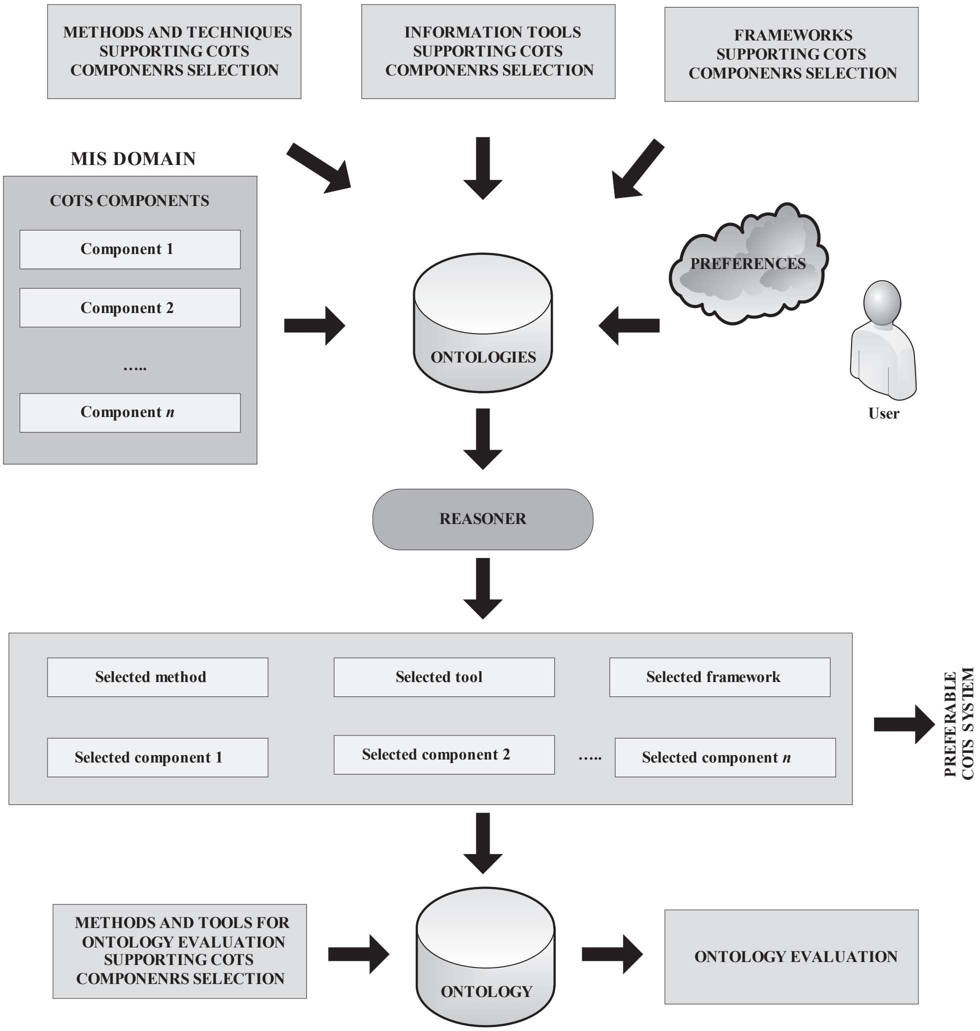

Figure 2. The phases of building COTS ontology

results is performed using the evaluation methods and tools. The picture presents the general structure of ontologies supporting COTS selection and evaluation with the specified phases (Figure 3).

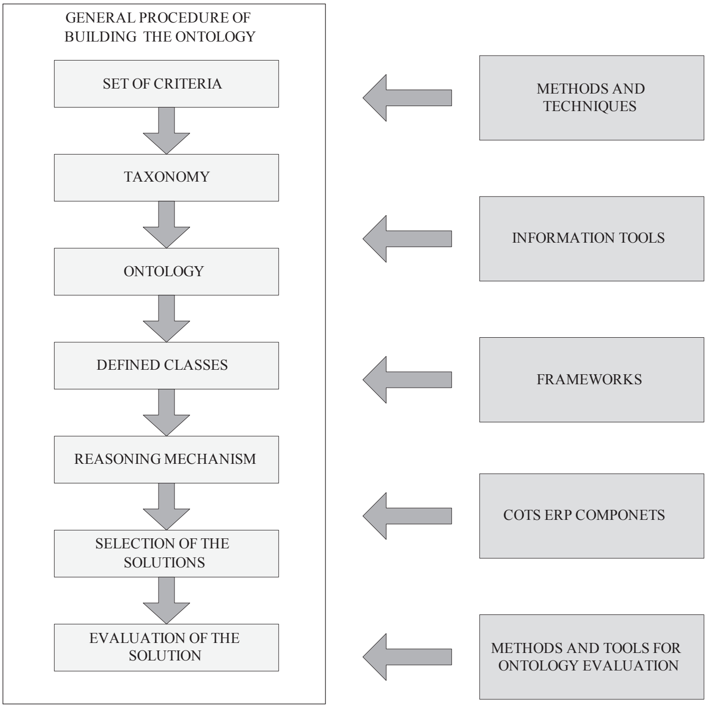

Figure 3. The general procedure of building the COTS ontology

4. The COTS ontologies – state of the art

The basis for each of the ontology construction was the thorough analysis of considered solutions and then the experiment of identification the set of criteria and subcriteria that were used to create the taxonomy. For each of the constructed ontologies, especially for methods and techniques supporting COTS components selection and evaluation, information tools and frameworks for COTS, the set of criteria was created on base of available characteristics of these methodologies. Then the information about COTS components derives from technical reports provided by the independent experts. On base of this information the particular features of COTS components were selected – it was a basis for creating the set of criteria. Moreover for the analysis of obtained results the thorough review of methods and tools for ontology quality evaluation was performed. The set of criteria was built on base of available characteristics of selected solutions in the similar way for methods and techniques supporting COTS components selection and evaluation, information tools and frameworks for COTS.

The defined set of criteria was a basis for a taxonomy construction for methods and techniques supporting COTS components selection and evaluation, information tools and frameworks for COTS, methods and tools for ontology quality evaluation and COTS ERP components. The aim of the taxonomy is to ensure systematization and classification for particular solutions. The taxonomy was a basis for an ontology construction as a next step. Particular ontologies were created including the information about each of considered solutions, and in many cases the names of criteria should be generalized. It helps in limitation the total number of the criteria in an ontology project. Furthermore, it improves the speed of computing provided by a reasoner.

The ontology was built using Protégé 4.1 program. The language which supports building the ontology is OWL (Ontology Web Language). It provides both the possibility for description of concepts and new additional functions for describing possible relationships. Each group of criteria is referred to subclasses with a higher level of specification. The whole ontology is based on the structure of tree. The developed ontologies with a huge number of classes and complex inheritance almost always require the tree class hierarchy [Horridge 2009]. The process of COTS ontology construction is determined by a few statements. The correctness of activity of the ontology is ensured by unified notation of the names of the classes, properties, objects and data types without using national letters, space bars and symbols. Moreover, it is necessary for reduplications in applied nomenclature for criteria and sub-criteria in each ontology to be non-extant. Then each of primitive classes should be disjointed from each other. Thereafter for each class both the slots should be defined and the proper values should be described.

For each of constructed ontologies the partition for existential and universal restrictions was made. It is obligatory for defining characteristics of particular COTS ERP components, methods and techniques, information tools and frameworks that support COTS selection and evaluation and methods and tools for ontology quality evaluation as well. After that for each of constructed ontologies the two hierarchies were created: asserted hierarchy and inferred hierarchy. The *asserted hierarchy* is created by an ontology designer on base of pre-defined *primitive classes*. Then the second one, *inferred hierarchy* proceeds from using a reasoner mechanism which considers *defined classes*. Using the reasoner provides to the user the set of results – the individuals sorted to the particular defined classes.

Each of constructed ontologies could be depicted graphically, both the whole ontology and its parts. The asserted hierarchy and inferred hierarchy can be showed in this way as well. Moreover, it is possible to ask the questions directly to a given ontology using description logic (DL). As a consequence, the user gets the answers for posed questions.

In view of the limited scope of this publication the selected examples of particular ontologies will be presented. The whole analysis encompasses 138 solutions which were divided into five ontologies. The main advantage of COTS ontologies is providing a systematic and repeatable knowledge about each of presented solutions. Each presented ontology enables the selection of a proper solution for a given problematic area. Thus, it provides a possibility to select the components in a simple and unique way including the set of criteria defined by a decision-maker.

The whole ontology encompasses the set of 5 criteria and 51 sub-criteria for 38 methods and techniques supporting COTS components selection and evaluation (APCS, CAP, CARE, CBCPS, CDSEM, CEP, CSID, COSTUME, COTS-Agent Based System, CRE, Cil, Colombo and Francalanci, DBCS, Erol and Ferrel, FCS, GOThIC, IusWare, Jung and Choi, Lai, MAS, MRETS, Merad and Lemos, MiHOS, Morera, OTSO, PECA, PORE, RCPEP, SCARLET, SMI, STACE, Scenario-based technique, Sedigh Ali, StoryBoard, Teltumbde, Wang, Wei and Wang, WinWin Sprial Model). For these solutions the set of 54 defined classes was defined. Figure 4 presents a small part of the methods and techniques ontology with general criteria assignment (COTS evaluation process, Criteria defining process, Criteria importance, Software evaluation, Type of preference information). Due to the limited scope of the publication, the sub-criteria for each of the ontologies are not presented in detail.

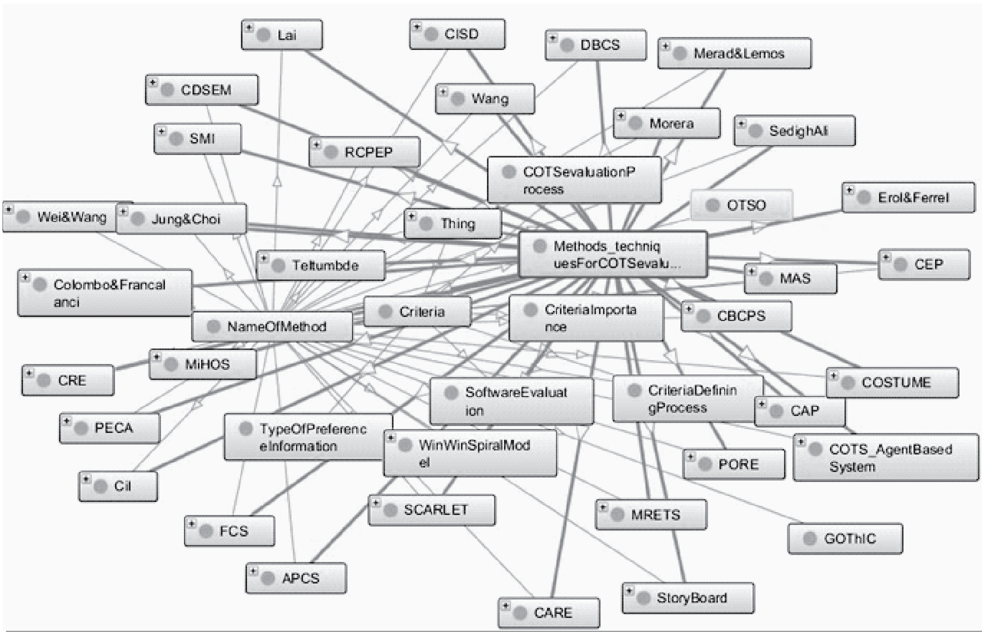

Figure 4. Ontology for methods and techniques supporting COTS components selection and evaluation process

Another ontology for information tools includes 24 solutions (GAM (Goal Argumentation Method), GQM (Goal Question Metrics), Strategic Dependency Model (SDM), Cognitive Tasks Analysis, SIBYL, EKD, Agora, SCB (Software Commerce Broker), IPSCom, MoreCOTS, Sema-SC (Semantic Component Selection), GBTCM (Goal-Based Taxonomy Construction Method), GBRAM (Goal-Based Requirements Analysis Method), GOThIC (Goal-Oriented Taxonomy and reuse Infrastructure Construction), Ontomanager, SymOntoX, Hierarchical Agglomerative Clustering (HAC), PLIB, INSEAS, ADIPS Framework-Faceted-Browsing, Rascal, Model Driven Architecture – MDA, Semantic-Based Technique, CompoNex-Browsing) and the set of 8 criteria and 32 sub-criteria and 18 defined classes as well. Figure 5 presents the set of criteria (Additional improvements, Advanced searching mechanisms, COTS selection supporting process, Classification criteria, Phase of development, Semantic technologies, Method of searching components). Due to the limited scope of the publication, the sub-criteria for each of the ontologies are not presented in detail.

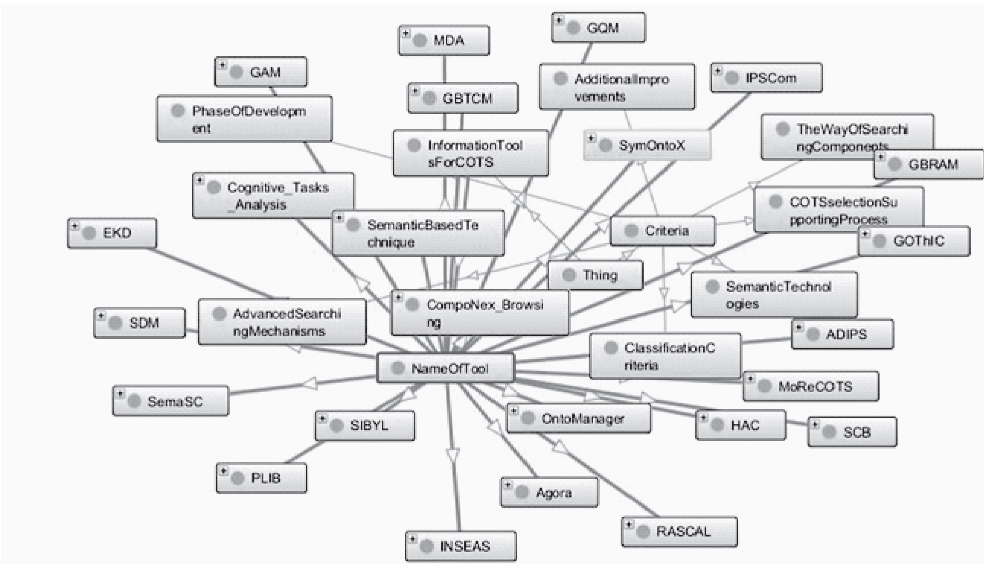

Figure 5. Ontology for information tools supporting COTS components selection and evaluation process

The ontology for frameworks assembles the set of 4 criteria and 22 sub-criteria. Thus for 15 frameworks 24 defined classes were described. The most expanded ontology was built for COTS ERP components. The schema depicts selected frameworks (CAP, CBCPS, CEP, CRE, Carney and Long, Carney and Wallnau, Delta Technology Framework, FCS, Framework ISO9126, Morisio and Torchiano, OTSO, PORE, SSEF, STACE, Torchiano and Jaccheri) and the general set of criteria (Application, Evaluation, Evaluation process, Requirements) (Figure 6). Due to the limited scope of the publication, the sub-criteria for each of the ontologies are not presented in detail.

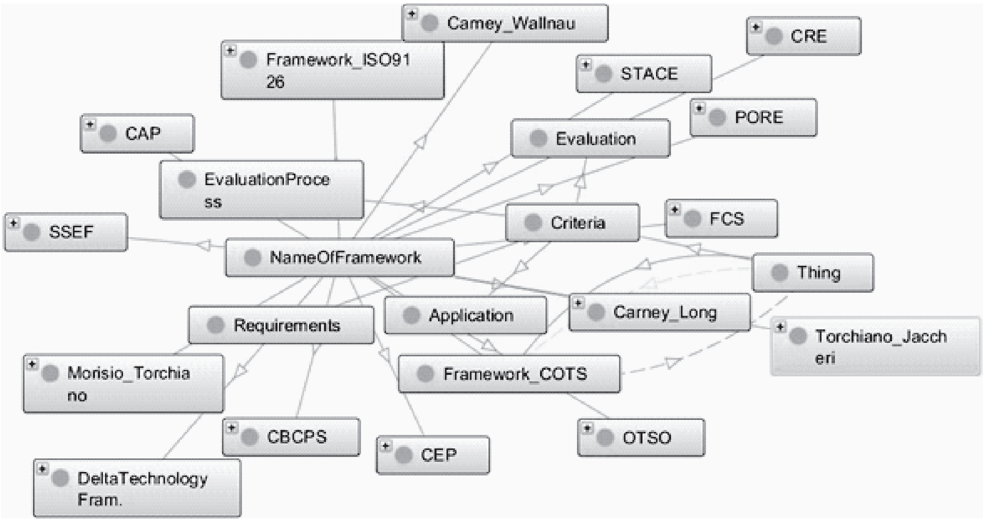

Figure 6. Ontology for frameworks supporting COTS components selection and evaluation process

It encompasses 50 solutions (MAAT, Maconomy, Sage ERP X3, System Zarzadzania Forte, Polka SQL, Asseco WAPRO, Microfost Dynamics AX, Graffiti ERP, Navireo, SZYK 2, Epicor, TETA Constellation, Comarch Altum, Digitland Enterprise, Bastion ERP, QAD, STER ERP, Oracle E-business Suite, ISOF, Berberis, JDEdwards Enterprise Oracle, Asseco SAFO ERP, Comarch CDN XL, Streamsoft PRESTIZ, Ewka SQL, Microsoft Dynamics NAV, Jeeves Universal, Comarch Egeria, MAKS V, Impuls5, MONITOR ERP, POSitive Retail, SFIX, Eclsoft, Rekord ERP, SEMIRAMIS, humansoft Hermes SQL, Intea, SENTE eSystem, IFS applications, PRO NES, MAX eBiznes, Madar ERP, Hornet ERP, proALPHA, Epicor iScala, Asseco SOFTLAB ERP, Xpertis, SAP ERP, SIMPLE ERP) with the set of 19 criteria and 242 sub-criteria. COTS ERP ontology includes 185 defined classes. The last ontology for method and tools for ontology quality evaluation consists of the set of 7 criteria and 29 sub-criteria. For 11 methods and tools (CORE, OntoKBEval, CleanONTO, AKTiveRank, OntoMetric, Natural_Language_Application_metrics, OntoQA, OntoManager, OntoClean, ODEval, EvaLexon) 29 defined classes were defined as well. Owing to the limited space, the ontologies for COTS ERP components and methods and tools for ontology quality evaluation cannot be presented in detail.[1]

Thus, the practical example of the ontology application was provided. The exemplary results of using COTS ERP ontology were presented below. The user defines the set of requirements (for example the user is looking for the system which supports the logistics). Then after the reasoning process the selected solutions that fulfill the set of criteria are provided. It is worth noticing that for each of ontologies

[1] http://www.erpstandard.pl.

it is possible to define many different queries. The more specified set of criteria, the smaller number of results.

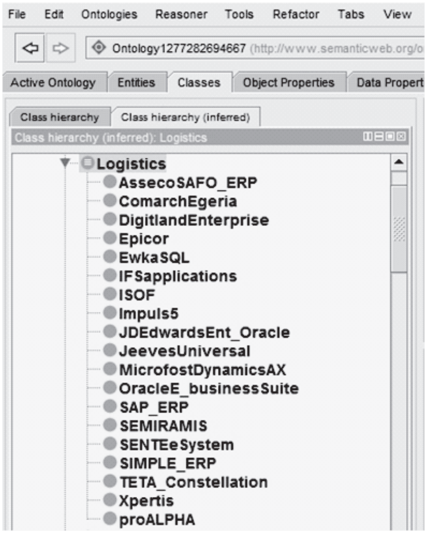

Figure 7. The practical example of using COTS ERP ontology

The criterion Logistics is a kind of defined class that encompasses the solutions that fulfill the more specified criteria such as *Distribution and logistics*, *Transport management*, *Warehouse management*, *Supplier relationship management*, *Supply chain management.* The reasoning mechanism computes and provides the results: Asseco SAFO ERP, Comarch Egeria, Digitland Enterprise, Epicor, Ewka SQL, IFS applications, ISOF, Impuls5, JDEdwards Enterprise Oracle, Jeeves Universal, Microsoft DynamicsAX, Oracle E-business Suite, SAP ERP, SEMIRAMIS, SENTE eSystem, SIMPLE ERP, TETA Constellation, Xpertis, proALPHA (Figure 7).

5. The formal way of COTS ontology description

Each of presented ontologies can be described in a formal way. General aim of using a formal language is to note available information from Semantic Web in a unique way. Furthermore, the standard of the notation should be processed by machines and allow the exploitation and modification of existing resources for obtaining knowledge from existing knowledge resources using a reasoning mechanism as well.

Description logic (DL) is a theoretical base for OWL language. Knowledge base of description logic (Knowledge base DL) is divided into two parts: TBox and ABox [Baader et al. (Eds.) 2002] (Figure 8).

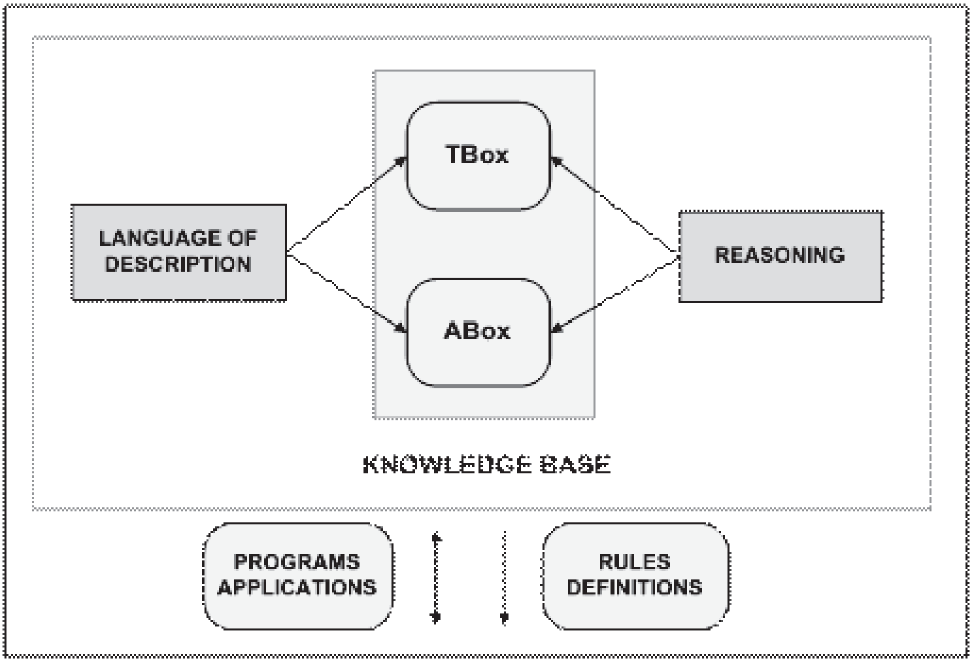

Figure 8. The knowledge representation system with a knowledge base on base of description logic

Source: own elaboration on base of [Baader et al. 2002].

TBox is a terminology and a set of axioms describing a domain structure. Then ABox is a set of axioms that describe a particular data. TBox terminology allows to identify concepts which are used to universe description. The relationships between concepts are also described by TBox. However, the reality description is provided by ABox which organizes universe elements (individuals) to particular concepts. It indicates the relationships between individuals using binary relations.

For each of COTS ontologies the formal description was provided. As an example the small part of description logic for methods and techniques supporting COTS components was shown (Table 1). The formal description was provided for each of author's ontologies to enable machine processing. The space limitation of this paper does not allow presenting all the results.

Table 1. Formal description of the ontology for methods and techniques supporting COTS components selection and evaluation

Class: **Methods_techniquesForCOTSevaluation**
LowCOTScomponentsEvaluation ≡ **Methods_techniquesForCOTSevaluation** and hasCOTScomponentsEvaluation some integer [<="4" (integer)]
LowLevelOfEvaluationReliability ≡ **Methods_techniquesForCOTSevaluation** and hasEvaluationReliability some Low
LowLevelOfEvaluationReliabilityEquivalent ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some (Criteria and hasEvaluationReliability some Low)
and hasCriterion some AHPmethodApplication
Evaluation_HeuristicAlgorithmApplication ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some HeuristicAlgorithmApplication Evaluation_MCDAmethodApplication ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some MCDAapplication
Evaluation_ExpertMethodsApplication ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some ExpertMethodsApplication
Evaluation_QualityModelsApplication ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some QualityModelsApplication
Evaluation_RiskDrivenApplication ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some RiskDrivenApplication
Evaluation_SoftwareDescriptionFromRepositoryResources ≡ **Methods_techniquesForCOTSevaluation** and hasCriterion some SoftwareDescriptionFromRepositoryResources
Class: **Criteria**
LowLevelOfEvaluationReliabilityEquivalent ≡ Methods_techniquesForCOTSevaluation and hasCriterion some (**Criteria** and hasEvaluationReliability some Low)
MediumLevelOfEvaluationReliabilityEquivalent ≡ Methods_techniquesForCOTSevaluation and hasCriterion some (**Criteria** and hasEvaluationReliability some Medium)
HighLevelOfEvaluationReliabilityEquivalent ≡ Methods_techniquesForCOTSevaluation and hasCriterion some (**Criteria** and hasEvaluationReliability some High)
Methods_techniquesForCOTSevaluation ⊆ hasCriterion some **Criteria**
isCriterionOf Domain **Criteria**
hasCriterion Range **Criteria**

The terminology proposed below describes the concepts and defines the relationships between them. Axiom ≡ indicates the equivalence between concepts. Moreover, axiom $\subseteq$ defines the inclusion. The information about domain and range of the ontology was provided as well. Thus, some additional parameters were provided. The quantifier restrictions were defined (some as an existential restriction – defines also as ∃) [Krotzsch, Rudolph, Hitzler 2008]. The existential restriction constrains the relation in which the individual participate. Moreover, the object properties were defined: *hasCriterion* and its inversion *isCriterionOf.*

6. Conclusions

The general aim of this paper is to present the ontologies supporting COTS software components selection and evaluation. The process of COTS ontology construction was presented in details. The ontology was built for methods and techniques, information tools and frameworks, methods and tools for ontology evaluation and COTS ERP software components as well. The analysis encompassed 138 solutions. The proposal of a formal description of projected ontologies was provided. The application of the ontology allows to provide a systematic and repeatable knowledge about available solutions on the market. Moreover, the decision-maker does not have a broad knowledge about both particular components and methods and even so he or she can make a reasonable choice.

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ONTOLOGIE WSPOMAGAJĄCE PROCES DOBORU I OCENY SKŁADNIKÓW OPROGRAMOWANIA COTS

Streszczenie: W niniejszym artykule przedstawiono ontologie wspomagające proces doboru i oceny składników COTS. Przedstawiono główne założenia dotyczące projektu oraz budowy ontologii. Ponadto omówione zostały poszczególne kroki budowy ontologii dla COTS. Zaprezentowano również przykładowe fragmenty ontologii metod oraz technik wspomagających dobór i ocenę COTS, narzędzi informatycznych oraz frameworków, metod i narzędzi oceny jakości ontologii oraz ontologii składników COTS ERP. Całość kończą wnioski z przeprowadzonych badań.

Słowa kluczowe: ontologia, oprogramowanie COTS, wybór i ocena COTS, składniki COTS, metodologia COTS.